April 28, 1988

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Ms. Alice C. Fuerst
Cherokee County Project Manager
Superfund Branch
Waste Management Division
U.S. Environmental Protection Agency
Region VII
726 Minnesota Avenue
Kansas City, Kansas 66101

RE:      Cherokee County CERCLA Site

Dear Ms. Fuerst:

These comments on the "Final Draft Groundwater and Surface Water Operable Unit Feasibility Study, Galena Subsite, Cherokee County Site, Kansas, February 26, 1988, WA No. 102-7L37.0" (OUFS) are submitted on behalf of the following potentially responsible parties (PRPs): AMAX Inc., ASARCO, Inc., Eagle-Picher Industries, Inc., Gold Fields Mining Corporation, N.L. Industries, Inc., St. Joe Minerals Corporation and Sun Company, Inc. These comments on behalf of the above PRPs are not an admission or waiver of any defense (and should not be considered or construed as an admission or waiver) concerning their potential liability for response costs at the Cherokee County Site, or concerning the propriety of the U.S. Environmental Protection Agency's (EPA's) activities there.

As a preliminary matter, we would like to note that EPA originally provided only thirty (30) days (to April 6, 1988) to review and submit written comments on the OUFS. The PRPs did not believe that 30 days were sufficient to thoroughly review the OUFS and extensive new supporting information (including 2 appendix volumes of several hundred pages with raw data, modeling results and data evaluations) and to prepare detailed comments. Accordingly, the PRPs requested a 90-day extension of the comment period (letter to Alice C. Fuerst from Peter Keppler dated March 15, 1988). In follow-up telephone conversations, EPA indicated that they would not act on our request until after their scheduled meeting with the PRPs on March 30, 1988 --- after which

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time only 7 days of the original comment period remained.  At the March 30
meeting, EPA responded by extending the formal comment period by 24 days to
April 30, 1988.  While the extension is genuinely appreciated, we believe that
the extended comment period is still too short for meaningful public
participation -- especially in light of EPA's failure to respond promptly to
our original request for an extension.

Attachment A to this letter is a technical review of the public health
and environmental risk assessment and related areas prepared for the PRPs by
Charles A. Menzie & Associates.  Rather than attempt to summarize and
incorporate the comments contained in the technical review, we have
incorporated this review document in its entirety -- as part of the PRPs
comments on the OUFS.

## General Comments

As we have stated on numerous occasions in the past, the PRPs are gravely
concerned with the EPA's erroneous and unsupportable position that historical
mining activities are the sole cause of the elevated metallic ion
concentrations recorded in the shallow aquifer, surface waters and soils
within the Galena Subsite.  This position is perpetuated in the Groundwater
and Surface Water OUFS.

The EPA's position in the Groundwater and Surface Water OUFS, as in
previous portions of the Remedial Investigation/Feasibility Study (RI/FS) for
the Cherokee County Site, has been that historical mining activities have
changed the surface and subsurface characteristics of the area and that these
changes, through resulting alterations in the hydrological systems, have been
the sole or major cause of the elevated metallic ion concentrations recorded
in the shallow aquifer in the vicinity of the site and in the surface waters
draining the site.

The PRPs acknowledge the fact that historical mining activities created
underground voids and resulted in the placement of mine wastes on the surface.
These actions and resulting alterations in hydrology have exposed some of the
naturally occurring sulfide minerals to more oxidizing conditions and, thus,

altered the mobilization of contained metallic ions.  However, comparing the tonnage of mineralized material assumed by the EPA to remain underground (page 6-7 of the OUFS) with the quantity previously mined (page B-11 of the OUFS) reveals that mining activities removed more than 80 percent of the mineralized material naturally occurring in the Galena Subsite.  Accordingly, by EPA's own estimates, mining has removed a majority of the sulfide materials which were naturally oxidizing and releasing metallic ions to the environment.  We believe the effect of the removal of this source has more than offset the effect caused by the increase in exposure for a fraction of the remaining mineralization.  In any event, EPA has failed to quantify or otherwise take these factors into account in its approach to this OUFS.

The PRP's are also gravely concerned with the obvious bias and slanted interpretations of results in an attempt to make the point that historical mining activities are the cause of the existing water quality conditions within the Galena Subsite.  For example,throughout the OUFS the term acid mine drainage (AMD) is misused to also include the oxidation of pyritic materials not associated with mines nor discharges associated with mines.  Also, from the information contained in the OUFS the reader is led to believe that EPA has data to document that in its pre-mining condition Short Creek supported a diverse biota.  From our understanding of pre-mining metallic ion concentrations that likely occurred in Short Creek (see discussion below), and from data available from other undisturbed areas where a stream flows through a sulfide mineralized zone -- for example Red Dog Creek in Northwest Alaska (EPA, 1984) -- we strongly doubt that Short Creek ever supported a diverse biota.

The PRP's position throughout the RI/FS for the Cherokee County Site has been that, although mining has caused changes, the concentration of metallic ions observed in the shallow aquifer and surface waters today are not significantly different than the concentrations that occurred in the pre-mining condition.  The PRPs have repeatedly requested that the EPA take the naturally occurring background concentrations into consideration in the overall RI/FS, especially in the development of the overall goals and objectives of any remedial action.  The Kansas Department of Health and

Environment also acknowledged the potential for naturally occurring elevated concentrations of some ions and recommended in their letter to EPA dated May 12, 1987 (Gayula F. Kovach to Alice C. Fuerst) that "it would be appropriate to estimate what these (background) conditions are." The EPA has not responded to these requests and we believe the consequences, not surprisingly, are reflected in the results of the Ground Water and Surface Water OUFS: by EPA's own admission in that document, none of the developed alternatives will meet the unrealistic long-term goals and objectives established by the EPA for the Galena Subsite.

Since the EPA was not willing to address the background conditions in a meaningful fashion, the PRPs retained a group of highly experienced experts to investigate and to prepare a report concerning the likely pre-mining conditions within the Galena area. That report, entitled "Pre-mining Surface and Shallow Ground Water Quality in the Vicinity of Short Creek, Galena, Kansas" (Angino, 1988) was previously submitted to EPA by the PRPs under a cover letter from Peter Keppler to Alice C. Fuerst dated March 22, 1988. It concluded that because of normal weathering and chemical attack of the naturally exposed sulfide ore body that occurred at Galena, elevated concentrations of metallic ions were undoubtedly present in Short Creek and the shallow groundwater system in pre-mining time, at levels that exceed current standards and the targets established in the RI/FS for any remedial actions at Galena.

This conclusion is confirmed by the water quality modeling contained in the Ground Water and Surface Water OUFS for Remedial Alternative 2. Under this alternative, all surface mine wastes would be removed, all shafts and underground voids would be backfilled and surface features would be improved to a condition approximating that which likely occurred in the pre-mining period. Accordingly, based on the fact that the underground workings would be filled with relatively inert backfill rather than sulfide mineralization, this alternative conservatively approximates the pre-mining condition for the subsite. The water quality modeling contained in the OUFS predicts that -- even after remediation to those pre-mining conditions -- the concentration of metallic ions will exceed the EPA-defined legally applicable or relevant and

appropriate requirements (ARARs).  The PRPs believe that the predicted concentration of metallic ions would be significantly higher if the mine voids were still filled with sulfide mineralization (commercial ore), as occurred in the actual pre-mining condition, rather than with the inert backfill mixture -- thus further supporting the conclusions of Dr. Angino's report.

In summary, we acknowledge that mining has caused some changes to the physical and hydrological characteristics of the Galena Subsite, but we strongly disagree with the information presented in the Ground Water and Surface Water OUFS on the extent of these changes and the effect that these changes may have had on the background metallic ions concentrations in the shallow aquifer and surface waters of the Galena Subsite.  In light of the conclusions presented in the Angino report, we believe that EPA is obligated to re-evaluate not only its conclusory position concerning the purported effect of mining on water quality, but also its fundamental approach to the goals, objectives and targets for any remedial actions at the Galena subsite (as well as the Cherokee County site as a whole).

Finally, the PRPs provided extensive comments on the EPA characterization and evaluation of the ground water resources in our comment letters on the Alternative Water Supply (AWS) OUFS (letter to Alice C. Fuerst dated December 10, 1987) and the Site-Wide Water Supply Inventory Technical Memorandum (letter to Alice C. Fuerst dated February 1, 1988).  Since this OUFS tends to incorporate and expand on the flaws we commented upon in these earlier letters, we are requesting that the above letters be incorporated by reference into these comments and the administrative record for this OUFS.

## Public Health and Environmental Risk Assessment Comments

The PRPs can understand the need to be conservative in the assessment of potential public health and environmental risks, but the assessments and supporting assumptions contained in Section 3 of the OUFS are totally unrealistic and unprofessional.  As noted in Charles A. Menzie & Associates' technical review (Attachment A), the methods used in the assessment are outdated and the assessments are not meaningful.  As a preliminary but

significant matter, on page 1 of the OUFS it states that "This Groundwater/Surface Water OUFS was developed with the assumption that EPA's selection of a water supply remedy, expansion of the municipal water system, will be implemented." Yet, in direct contradiction of that statement, ingestion of contaminated drinking water from the shallow aquifer is described by EPA on page 3-19 as one of the two primary exposure pathways included in the assessment. Further, the estimated contaminant intakes calculated for the Groundwater and Surface Water OUFS are different than those included in the AWS OUFS and seriously call into question the risk assessment and remedy selection contained in the AWS OUFS. Accordingly, the PRPs believe that the AWS OUFS Record of Decision (ROD) must be reopened and reconsidered in light of EPA's revised contaminant intake calculations.

The exposure pathways for surface water included in the OUFS are incidental ingestion and dermal absorption during swimming. On page 3-10 it is noted that Schirmerhorn Park, located at the southern edge of Galena on Shoal Creek, is a popular picnic and swimming resource for the entire area. Yet the risk assessment is based on a child swimming one hour each day -- including during the winter -- in the area waters with the highest metallic ions concentrations (Short Creek, Owl Branch or mine ponds). As noted, most swimming likely occurs in Shoal Creek at Schirmerhorn Park where, as shown on page 3-10, the maximum recorded concentrations of metallic ions are below drinking water standards. Inspection of the Galena subsite clearly suggests that any swimming in other surface waters would likely be extremely limited and infrequent. Further, the exposure pathways considered are only appropriate to full body contact recreation activities and would not apply to wading and other activities. Short Creek, Owl Branch and other surface waters included in the assessment, because of their physical characteristics, simply cannot provide for full body contact recreational activities. Even if they did, the estimated exposure by ingestion and dermal absorption contained in the OUFS are grossly in error as noted in Attachment A.

To achieve the contaminant intakes projected for the ingestion of surface solids by children, we are to believe that a 10-Kg child (approximately one year old child) would travel _daily_ to the mine waste areas and selectively

consume one gram of mine wastes containing the highest concentration of metals. While we can understand how an unsupervised older child may, through the course of playing, occasionally and incidentally ingest some dirt and waste material, we believe that the assumptions made for this pathway are totally unrealistic, and that any possible risks to a 10-kg child (who presumably would be supervised) are grossly overstated. As discussed in Attachment A, a more appropriate estimate for ingestion of surface solids by children is about 100 mg/day from all sources. Indeed, even for an older child the ingestion of one gram of waste would be unlikely and certainly not a daily occurrence. Further, if the ingestion is to occur over an extended period of time, it would be more reasonable to assume that the material consumed would contain the average, rather than maximum, concentration of metals. This is especially true given the fact that the EPA has determined as part of their waste characterization study, as summarized in Appendix A.4 of the OUFS, that the maximum concentration of metals occurs in rock and not in material that could be incidentally ingested. Finally, and significantly, it should also be noted that in the pre-mining condition the ore body was exposed at the surface throughout this area and that this exposure pathway is a natural feature.

The evaluation of the exposure from the ingestion of fish is another example of slanted presentation of information. Under this topic on page 3-17 of the OUFS it states "Fish in these streams and lakes naturally bioaccumulate certain metals. Ingestion of these fish may in turn result in exposure to humans." Since fish do not occur in Short Creek, this comment must refer to the Spring River and Empire Lake. Yet, on pages 88 and 93 of the Phase I Remedial Investigation Report for the Galena Subsite it states "Results (fish tissue analysis) suggest that bioaccumulation of metals is not occurring to any extent in game fish from Empire Lake, and the quantity of metals in forage and game fish collected in Empire Lake is similar to amounts in forage fish collected from various locations in Kansas." Accordingly, the information presented in the OUFS is not a fair and factual presentation of the available information. Further, the OUFS states on page 3-17 that "Contaminant intakes were estimated by assuming 70-Kg individuals consume 6.5 grams of game fish

per day ....." However, on page 3-18 it states that "For children, the exposure scenario consists of a 10-Kg child consuming 1 liter of contaminated groundwater, 1 gram of contaminated mine waste, 50 ml of contaminated surface water and 6.5 grams of fish per day." It is obvious that the 6.5 grams of fish per day was to apply to an adult; however, in the final analysis it appears that this quantity was also used for 10-Kg children. While some adults may consume 6.5 grams of fish per day, it is unlikely that a one year old child would consume this amount.

Overall, the PRPs believe that the assumptions made in the public health assessment are totally unrealistic and that this, along with the use of maximum contaminant concentrations for each of the exposure pathways, has resulted in grossly over-estimating the total contaminant exposure. These unrealistic contaminant exposures were then compared to a variety of standards -- all of which have their own built-in safety factors to account for uncertainties -- to produce an unacceptable and unscientific assessment of potential hazards to public health.

The environmental risk assessment contained in the OUFS is very straight-forward and consists of comparing the observed water quality in the surface waters to the applicable state and federal water quality criteria for the protection of aquatic life. The comment period provided was not adequate to review the raw data or to validate the summaries provided. Accordingly, we cannot comment in detail on this assessment. However, we do have some general comments.

The environmental assessment assumes that in their background condition (pre-mining), the Spring River and its tributaries were not affected by elevated concentrations of metallic ions and that any exceedences in water quality criteria for metallic ions are the direct result of mine drainage from historical mining operations. As discussed earlier and supported by Dr. Angino's report, the waters of Short Creek and other streams in the Cherokee County Site draining mineralized areas contained elevated concentrations of metallic ions prior to any mining activity. Streams flowing directly over or incised into sulfide minerals, such as the segment of Short Creek, likely had significantly elevated concentrations of metallic ions and very limited

aquatic biota. A very similar situation has been reported by the EPA for Red Dog Creek in Northwest Alaska (EPA, 1984). These tributary streams have contributed metal loadings to Spring River long before mining was initiated in the district.

In addition to the natural sources of metallic ions to the waters of the subsite, there are many documented non-mining manmade sources of metal loadings to the Spring River and its tributaries. One of these sources, Farmers Chemical Company's fertilizer plant, contributes significant loadings of nutrients and metallic ions to Short Creek immediately upstream of the Galena Subsite. Although the OUFS attempts to downplay this source, we believe the information in Gold Fields Mining Corporation's September 25, 1987 comment letter to EPA clearly demonstrates that this is a significant source of aluminum, cadmium, nickel, zinc and other contaminants to Short Creek. The concentrations of zinc and cadmium in Short Creek immediately downstream of this facility are more than four times the applicable water quality criteria for aquatic life. The PRPs have consistently requested that the EPA identify Farmers Chemical Company as a PRP at the Cherokee County Site, but to date we are not aware of any action by EPA on that matter.

On pages 3-58 and 3-59 of the OUFS the EPA continues to attribute the reduced diversity of macroinvertebrates in Spring River downstream of Empire Lake to elevated concentrations of metals. As discussed in an earlier comment letter (letter to Alice C. Fuerst dated October 19, 1987) we do not believe the existing data is sufficient to support this position, and, we believe other factors could be responsible for the noted diversity reductions.

## Goals and Objectives and Degree of Cleanup Comments

The OUFS establishes short-term and long-term goals for the remedial measures developed for the Galena Subsite. As stated on page 4-11 of the OUFS, "the long-term goals for the selected remedial measure are to protect human health and the environment through attainment of MCL's for groundwater and AWQC for surface waters within the Galena Subsite and in the Spring River adjacent to and downriver of the subsite." As discussed above, and at the

EPA/PRP meeting on March 30, 1988, Dr. Angino's report amply demonstrates that achieving these goals -- which, as discussed below, does not seem possible -- will result in conditions better than those naturally occurring in the Galena subsite.   Under those circumstances, we believe that the long-term goals identified in the OUFS -- which may generally be desirable objectives -- are inappropriate for remedial action at the Galena subsite, and are therefore arbitrary and capricious in the context of the present OUFS.   They are also unlawful and outside the scope of CERCLA.  See Section 104(a)(3)(A).

Further, the short-term goals are merely general objectives:  "to improve groundwater quality and reduce metal loadings to the surface water system." Id. These goals are not quantified, and are clearly not designed to meet the contaminant-specific ARAR's specified in the long-term goals.  Although not clearly stated, it is obvious that the overall approach of the OUFS, including the development, screening and analysis of remedial alternatives, is predicated on the assumption that achievement of the short-term goals will somehow bring about achievement of the long-term goals.  For example, on page 1-6 of the OUFS it states "The overall purpose of this OUFS is to provide a basis for selecting remedial actions that will achieve the stated short-term goals and thereby, protect public health and the environment from mining-related contaminants in the Galena Subsite groundwater and surface water systems as stated in the long-term goals."   However, the OUFS does not indicate how achievement of the short-term goals will bring about achievement of the long-term goals, or when the long-term goals will ultimately be achieved, if ever.  Indeed, even the OUFS acknowledges the uncertainty in this assumption by stating on page 8-45 that "ARAR's may be achieved in the long-term as an indirect result of the remedial actions.  This prediction cannot be made with available data."

Because the short-term goals are vague, general concepts, and because the Angino report strongly suggests that the long-term goals are unrealistic to begin with, the Agency has not met its burden of demonstrating that the short-term goals are an appropriate basis for selecting a remedial action.  Indeed, because the OUFS itself states that the selected alternative will not meet contaminant-specific ARAR's specified as long-term goals (pp. 34-36), we

believe that the short-term goals identified in the OUFS for remedial action at the Galena subsite are inappropriate, arbitrary and capricious, and outside the scope of CERCLA. See Section 104(a)(3)(A).

Accordingly, the PRPs believe that the overall approach used in the OUFS is fundamentally flawed and that implementation of any of the defined remedial actions will (as discussed later) delay rather than facilitate the establishment of the stated long-term goals. In an earlier letter to EPA on the site remediation goals (letter to Alice C. Fuerst dated August 28, 1987), it was noted that several of the long-term goals were unrealistic and unattainable because of EPA's failure to consider naturally-occurring background concentrations in their formulation. We believe that that point is amply demonstrated by the fact that none of the alternatives considered for detailed analysis will achieve the stated long-term goals.

## Surface Waste Comments

EPA has defined mine wastes in the OUFS as being a "collective term that includes bullrock, dump material, chat, scattered minor amounts of slag, and trace amounts of tailing" (Appendix A, page A-11). However, as discussed below, in its activities carried out to characterize this waste, EPA appears to have concentrated exclusively on piles of broken rock (bullrock or dump material) and ignored the chat (tailing from gravity separation processes) which constitutes some 58% of the surface waste at the Galena subsite. Preliminary sampling of chat by the PRPs indicates that the chat is much lower in lead content than the coarse rock sampled by EPA. Because EPA's determination of its remedial action and associated costs, as well as EPA's risk assessment, are based on the characterization of the waste, EPA has greatly underestimated the cost of its remedial action proposal as well as greatly overestimating the risk posed by the existence of mine waste piles.

An observer from one of the companies identified as a PRP was present during part of the sampling carried out by EPA. The observer was told by the sampling team that their instructions were to sample only coarse rock piles as their metal content would be higher than the chat piles. Subsequently, when

an engineer retained by one of the PRP companies to estimate the volume of mine waste performed his field activities, he came across 54 of EPA's 160 sampling point stakes and noted that all of them were located in rock piles and none in chat piles. This appears to contrast sharply with the statement in Section D.5.1.2.1 (Appendix D, OUFS Report) that "sample locations were selected to best represent the relative proportion of each waste type in each zone." Another significant error in the sampling procedure occurred when EPA confined its samples to the surface of the waste piles, except for two locations where trenches were dug to a depth of four feet. Given the large volume of heterogeneous materials present on the Galena subsite, the evident vertical and horizontal variations with a given pile -- let alone between piles of different materials -- and the limited biased sampling that was conducted of these materials, we do not believe that the overall waste materials present have been realistically or properly defined.

EPA has supplied voluminous field x-ray fluorescence (XRF) data in the OUFS. This data, by EPA's own admission, correlates poorly to calibration curves due to the "large particle size containing a heterogeneous size range of minerals" (OUFS Appendix D, Section D.5.2). The use of the field XRF during sample collection and sample compositing is likely to have biased the final results. The laboratory data is likewise suspect due to the way the samples were collected, mixed, and reduced. As noted above, significant sampling errors occurred. Subsequently, EPA divided the samples by cone and quartering, which is not a reliable method for coarse materials of a heterogeneous nature. All the handling of the samples, including cone and quartering, transporting, and laboratory size reduction offer the potential for gravity segregation of heavy minerals. It is noted, for example, that in seven of EPA's eight composite samples for the various waste zones iron is three to five times higher by the total metals ("wet chemistry") method than by XRF, but lead is only one to three times higher. This does not substantiate EPA's theory that the chemical digestion was incomplete (OUFS Appendix A, page A-14). However, it does suggest that the splits have segregated with respect to light and heavy minerals. If there were no differential settling of mineral fractions in the sample splits, then one

would expect similar multiples for iron and lead. The fact that the lighter metal (iron) had a higher multiple between wet chemistry and XRF results than the heavier metal (lead), suggests that the sample splits had segregated. With all the factors of sample bias and sample handling and processing errors considered, it is apparent that overall the sampling is unreliable; therefore, none of the analytical data can be relied upon.

EPA states that lead values determined by wet chemistry may be too low since laboratory XRF readings are higher (OUFS Appendix A, page A-14). We believe instead that an examination of the data suggests that the split of the sample analyzed by XRF had segregated with respect to light and heavy minerals.

As noted above, one of the PRP companies (AMAX Inc.) employed an engineer to carry out a field investigation of the volume of waste stored at the site (Attachment B). This investigation was prompted by a review of the information presented in the OUFS. EPA estimated that 283,000 cubic yards of waste were present within the eight areas delineated for sampling in the OUFS that comprise a total estimated area of 891 acres. This calculates to an average depth of less than 2-1/2 inches, which by simple field observation is a serious underestimate. The field work carried out for AMAX resulted in an estimate of 1,279,000 cubic yards of waste rock, chat, and other mine wastes.

EPA has also erred in calculating tonnage from the waste volume estimates. EPA has stated that 327,000 tons are present, indicating that a value of 1.15 tons per cubic yard was used. A standard earthmoving reference such as the "Caterpillar Handbook", indicates a value of at least 1.35 tons per cubic yard would be appropriate. This value would yield approximately 382,000 tons, based on EPA's erroneously low volume estimate and over 1,725,000 tons based on the PRP's volume estimate of 1,279,000 cubic yards.

Metals concentration levels for leachate from the surface mining wastes were determined by a modification of the EPA toxicity test, using a 48 hour "batch" extraction procedure with a 4:1 liquid to solid ratio of sulphuric acid. Thus, the sample was prepared (ground to the appropriate particulate size) then agitated for 48 hours with the sulphuric acid (see OUFS pages A-14, A-26). It is said that this will simulate conditions in the mine waste piles.

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These data are then used, together with the deionized water leach data (page
A-25), for the mass load modeling -- see Section A.7.3.3. pages A-86 through
A-90.   However, the EPA toxicity type test is a non-flow related, mass leach
test that does not simulate natural conditions, because it assumes a steady-
state and does not take into account intensity and duration of rain fall
events, drainage dynamics, and the highly permeable nature of the surface
wastes.   Accordingly, the laboratory leachate data and the modeling results
based on them cannot appropriately be used as a basis for developing remedial
alternatives in the OUFS.

## Preferred Remedial Action Alternative Comments

The remedial action alternative proposed by EPA and transmitted by letter
dated February 19, 1988 from Rowena L. Michaels, Director, EPA Region VII
Office of Public Affairs, was not specifically described or analyzed in the
OUFS.   The preferred alternative is described as "a modification of the
remedial actions described in the Operable Unit Feasibility Study report" and
is also described as "very similar to alternative three."   Although the
preferred alternative is very similar in some respects to Alternative 3, there
is one major difference in that the preferred alternative does not include the
partial backfilling of the mine voids.   Partial backfilling was a major
component of this alternative.   EPA's discussion of the proposed plan states
"The effectiveness of such action (partial backfilling) is questionable and,
therefore, is not preferred by EPA or KDHE."   However, neither the OUFS nor
the brief discussion of the preferred plan provides any analysis supporting
the EPA's position that partial backfilling is of questionable effectiveness.
Further, the OUFS employs modeling to predict the overall effectivenss of the
alternatives considered in detail and the deletion of the partial backfilling
component of Alternative 3 -- even if it had questionable effectiveness --
would change the overall modeled effectiveness of this alternative.

In our meeting on March 30, 1988, we specifically requested, and the EPA
agreed to provide, the analysis supporting EPA's decision to delete partial
backfilling and the modeling results of the overall effectiveness of the

preferred (i.e., modified) alternative. The EPA also acknowledged that at the time the modified alternative was selected, EPA had not modeled nor evaluated its overall effectiveness. As of this date we still have not received the supporting analyses; without this information or revised detailed cost estimates, it is impossible to thoroughly analyze the preferred alternative. However, we do have some comments on the estimated costs and overall technical feasibility of the preferred alternative.

The preferred alternative is described as providing for removal and treatment through milling and flotation of surface mine wastes, sale of metals removed from the wastes to help defray a portion of costs, and disposal of tailings into mine voids. The plan also calls for surface drainage diversions, recontouring of the surface to remove ponding and infiltration, and plugging or repair of wells extending into the Roubidoux Formation.

One of the PRP companies (AMAX Inc.) utilized sample splits obtained from EPA plus some samples obtained independently from chat piles to carry out a preliminary bench scale testing program for metallurgical recovery from this material (Attachment C). As noted above, the samples are not likely to be representative and have other deficiencies in terms of metallurgical testing. One such deficiency is the fact that by taking samples from the surface of the piles, the samples are of rock which has been subjected to many years of erosion by wind and rain. Because in the Galena area most mining was completed by the first decade of the 20th century, most of this rock has then been subject to over seventy years of such erosion. The result would likely be that clay materials are no longer present in the samples. Clay materials can have a very significant effect on extractive metallurgy processes causing additional process steps to be incorporated to prevent interference with recovery. Nevertheless, AMAX utilized the samples to do preliminary testing to determine if concentration or the eroded surface samples by conventional metallurgical means is feasible. It was found that a concentrate can be produced but a final determination of whether this concentrate is marketable has not been made. It should be noted that if the concentrate cannot be marketed, or if there are intermediate by-products of the process which cannot be marketed, disposal as hazardous waste could be required, causing a

significant additional expense rather than producing a cost offset as assumed in the OUFS.

Based on the bench scale testing, a preliminary flowsheet was designed for a recovery plant and cost estimates for constructing and operating the plant were made based on that flowsheet. One of the most significant factors involved in estimating the costs for the metallurgical plant concerns the amount of material to be processed and the time span over which the plant will operate. EPA has assumed, based on its estimate of 283,000 cubic yards (erroneously calculated by EPA to represent 327,000 tons) a plant capability of 700 tons per day would be operated 2 years on a 5-day, 24-hour-per-day work week basis to process all of the surface wastes. EPA further believes that a plant of this size could be skid-mounted so as to be movable to different areas of the Galena subsite.

As indicated in the attached AMAX report, a plant of this size would not be readily movable and would cost between $6 and $9 million (say $7.5 million) for its construction even if used equipment were employed. This compares to EPA's estimate of $610,000 for a plant of that size. In addition, EPA has estimated the operating and maintenance costs of this plant to be $3.96 per ton whereas the AMAX estimate is between $10.53 and $13.38 per ton (say $12 per ton). This would result in a two-year cost of $3.9 million compared to EPA's estimate of $1,296,000. When the more accurate estimates for the amount of waste rock present at the Galena subsite are taken into account (1,727,000 tons), the actual operating and maintenance costs become $20,724,000 and the time span of operation becomes ten years.

We further believe that EPA has underestimated the hauling costs for the material. Based on the AMAX report and the more accurate estimate of tonnage present, this cost would be $4.4 million as compared to EPA's estimate of $49,000. Finally, we believe that EPA's cost for tailing disposal is similarly underestimated. Much geophysical investigation and drilling of numerous bore holes will be required to locate mine openings. When tailing is placed into the openings, it will not flow uniformly like a liquid but will tend to mound up beneath the point of entry and plug the bore hole, thus requiring drilling of additional holes into the same openings. We have not

made a separate estimate of the tailing disposal costs but only note that we believe EPA's estimate to represent only a fraction of the actual cost that will be incurred.

Based on those items which we have calculated (excluding tailing disposal), our estimate of about $32.6 million compares to EPA's estimate of $2.155 million for the same portion of the remedial action alternative.

We have not attempted to estimate in detail costs of the other items required by the preferred remedial action alternative due to the lack of time available for comment. However, a preliminary review of these costs by experienced engineers leads us to believe that these costs -- for example the cost estimates for the surface water diversions, concrete lined channels, surface recontouring and deep well remediation -- have been significantly underestimated as well.

Finally, we note that EPA's proposed remedial action will have little effect on the metal levels available to enter the groundwater and surface water. This is because only between 40 and 70 percent of the lead is likely to be recovered by the proposed milling process, with similar low recoveries of other metals; it is also due to the fact that in-place mineralized rock will remain at or near the surface in many areas. EPA's choice of a remedial alternative fails to take into account volume estimates and metal content for exposed in-place rock. There are numerous areas where old excavations are exposed which appear to be geologically similar to material present in waste piles (which would be expected given the nature of the area and the type of excavations that were carried out). Thus, even if the surface waste piles were removed, vast amounts of similar rock would remain in place. The in-place rock would be expected to have an impact on the groundwater and surface water similar to that which might be caused by the waste rock piles, which further underscores the ineffectiveness of EPA's selected remedy and its inability to meet ARARs in the short- or long-term.

It is also important to note that the residual sulfide mineralization remaining underground would continue the natural geologic process of providing metallic ions to the shallow groundwater system and surface waters until these materials are totally oxidized and the contained ions are flushed from the

area.    If  the  estimates  of  the  quantity  of  mineralization  remaining underground  and  the  loadings  to  area  waters  given  in  the  OUFS  are  correct, then  under  the  existing  conditions  it  would  take  more  than  1,000  years  for  the residual  sulfide  mineralization  to  be  flushed  from  the  system.    (It  must  be emphasized  again  that  the  flushing  process  began  long  before  mining,  and accounts  for  the  naturally-occurring  elevated  metallic  ion  concentrations.) If  it  is  EPA's  objective  to  reduce  metallic  ion  loadings,  we  note  that measures  which  reduce  the  rate  of  oxidation  and  mobilization  of  metals,  as included  in  all  alternatives,  would  merely  <u>extend</u>  the  time  required  for  the contained  metallic  ions  to  be  flushed  from  the  system.    For  example,  if  an alternative  reduces  metals  loadings  by  50  percent  over  the  existing conditions,  it  would  take  more  than  2,000  years  for  the  contained  metallic ions  to  be  flushed  from  the  system.    During  this  flushing  period  the  metallic ions  concentrations  in  the  shallow  aquifer  and  surface  waters  would  continue to  exceed  the  ARARs  under  all  alternatives  considered  for  detailed  analysis  in the  OUFS,  as  indicated  by  the  modeling  conducted  by  the  EPA.    In  any  event,  we note  again  that  the  elevated  metals  concentrations  that  would  exist  during  the 1,000  year  period,  although  not  meeting  ARAR's,  would  approximate  natural  pre- mining  conditions  and  are  <u>not</u>  the  proper  subject  of  CERCLA  expenditures.

Finally,  as  discussed  earlier,  the  proposed  alternative  will  not  meet contaminant-specific  ARARs  in  the  short-term,  and  there  is  no  demonstration  or other  basis  to  conclude  that  they  will  be  met  in  the  long-term.    As  the  PRPs have  commented  in  the  past,  compliance  with  those  ARARs  is  technically impracticable  from  an  engineering  perspective,  due  in  large  measure  to  natural geologic  conditions,  and  there  is  accordingly  no  rational  basis  for  selecting the  preferred  alternative.

## No Action Alternative Comments

As  noted  in  the  OUFS,  the  no  action  alternative  was  retained  for  analysis to  provide  a  baseline  for  comparison  of  remedial  alternative  effectiveness;  it was  not  considered  as  a  potentially  viable  alternative.    The  PRPs  believe, based  on  the  information  contained  in  the  OUFS,  that  this  alternative  with appropriate  administrative  controls  could  provide  as  much  protection  to  human

health and the environment as provided by the currently proposed preferred alternative, and at significantly less cost.

The two primary exposure pathways identified in the OUFS are incidental ingestion of surface solids, and drinking of contaminated water from the shallow aquifer.  As discussed earlier, the drinking water pathway was the subject of the AWS OUFS and should not be considered in this action.  The potential incidental ingestion of solids pathway could be reduced as much, if not more, than the reduction provided in the preferred alternative with simple administrative actions.  These administrative actions could include fencing of potentially contaminated areas, posting of signs, and the implementation of public awareness meetings.  While these actions would not remove the source of potential contamination, they would reduce potential exposure to levels equal to, or lower than, that provided by the preferred alternative.

Likewise, the incidental ingestion and dermal absorption pathway -- although very insignificant exposure routes -- could be totally eliminated by prohibiting swimming in the identified contaminated waters.  Since there are few sites with contaminated waters that are physically suitable for swimming and there are popular noncontaminated alternative sites for water-based recreation, fencing, posting and other administrative controls should be very effective at eliminating this exposure pathway.

Accordingly, the PRPs believe that the no action alternative, with appropriate administrative controls, would be as effective as the preferred alternative in protecting human health and the environment and that this alternative, on balance, may be the most cost-effective alternative to consider.  We request that EPA re-evaluate the no action alternative as more than a basis for comparing other alternatives, and that EPA provide a detailed comparison of the effectiveness of this alternative, with appropriate and necessary administrative controls, to that of EPA's preferred alternative.

## Summary and Conclusion
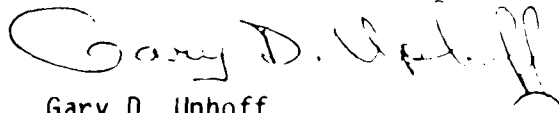
The PRPs believe that the comments contained in this letter clearly demonstrate that EPA's failure to properly acknowledge or take into account natural geologic conditions and phenomena occurring at the Galena Subsite has

resulted in an inaccurate description of the effects that mining has had on the area, a fundamentally flawed OUFS process, and the selection of a remedial alternative that cannot achieve its stated objectives. Accordingly, the PRPs believe that the only technically and legally supportable action is for EPA to acknowledge that, because of the natural geologic conditions, it is technically and economically impracticable to develop any effective remedial action, and to adopt the No Action Alternative. The No Action Alternative, with appropriate administrative actions to limit public exposure to metallic ions, would provide as much protection of human health as provided by the preferred alternative, and would not result in the unnecessary and unlawful expenditure of valuable CERCLA funds.

Thank you for your consideration of these comments and for including them in the administrative record for the Cherokee County Site.

Respectfully submitted,

ENVIRONMENTAL MANAGEMENT SERVICES COMPANY

Gary D. Uphoff
Principal

GDU:sam

On behalf of:
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ASARCO, Inc.
Eagle-Picher Industries, Inc.
Gold Fields Mining Corporation
N. L. Industries, Inc.
St. Joe Minerals Corporation
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Technical Review  of
Section 3 : Public Health and Environmental Risk Assessment,
Appendix A-5: Groundwater, and
Appendix A-7: Groundwater-Surface Water Interaction


in:   Final Draft Groundwater and Surface Water
Operable Unit Feasibility Study
Galena Subsite Cherokee County Site, KS


February 26, 1988
WA Number 102-7L37.0
US Environmental Protection Agency

22 April 1988


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# I. GENERAL COMMENTS

Charles Menzie & Associates have carried out a technical review
of three sections in the Final Draft of the Groundwater and
Surface Water Operable Unit Feasibility Study (OUFS) for the
Galena Subsite (US EPA, 1988b). This review focused on the
interpretation of data, the use of data, and the assumptions made
with regard to the performance of a risk assessment for the site.
We have compared the risk assessment methods used in the Final
Draft report with standard and state-of-the-art approaches that
are being used throughout the country. Overall, we find that the
approach used in the draft report is weak in a number of
respects. The method used is similar to some that had been in use
several year ago (i.e., similar assumptions, use of unrealistic
worst case scenarios). The methods for conducting risk
assessments have been advanced since these earliest risk
assessments were performed. Information has been developed
concerning assumptions related to exposures. General guidance has
been established on how to represent realistic exposure
scenarios. Unfortunately, few of these methods have been utilized
in the draft report and it suffers from many of the same problems
identified several years ago. As a result, the risk estimates
provided in the document are not meaningful, i.e., because they
are so unrealistic, they really don't provide information that
can be useful from a risk management standpoint. In order for a
risk assessment to serve a useful purpose it should convey useful
information. This is a point we underscore in our course at
Boston University and is one that most risk assessors would
concur with.


## A. Consideration of Background Concentrations

The study area near Galena, KS, has high concentrations of
several metals, including lead and zinc, in the minerals forming
the soils and rocks. In the past, people mined these ores
commercially. However, the OUFS for the study area does not
consider these natural conditions fully and properly. As detailed
below in the specific comments:

  o the public health risk assessment in Section 3 does not
    analyze the contribution and the effects of these natural
    concentrations in ground and surface waters and in
    soils,

  o the environmental risk assessment in Section 3 discusses,
    but does not quantify, the contribution and the effects
    of these natural concentrations in surface waters,

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o the ground water analysis in Appendix A-5 erroneously
    quantifies  the contribution of these natural
    concentrations in ground water, and

o the ground and surface water model developed in Appendix
    A-7 compounds and propagates some of the errors created in
    Appendix A-5.


Overall, the original technical report does not properly and
consistently  distinguish between human health and environmental
stresses from:

o concentrations of metals in ground and surface waters and
    in soils  from (i) natural concentrations, (ii) the former
    mines, and (iii) the former smelter,  and

o concentrations of other pollutants from other sources,
    such as  those from municipal sewage treatment plants,
    from municipal nonpoint source  runoff, from agricultural
    nonpoint runoff, and from upstream and upgradient
    contributions.  Without making and quantifying the effects
    of these important distinctions, the  report, sometimes
    explicitly and sometimes implicitly,  implies that all the
    environmental problems and stresses in the study area have
    a single and  consistent source -- the abandoned mines.
    While the mines may be a source of  some of the current
    adverse conditions, the report makes little or no attempt
    to  quantify and then partition or assign the
    responsibility among the possible  sources.


## B. Consideration of Zones and Subareas

The Galena Subsite area is far from homogeneous. Of the 18 square
miles of  land in the Galena Subsite, some 900 acres of it - or
approximately 8 percent  - is disturbed or covered with mining
wastes. Of the many miles of stream in  the subsite, Short Creek
is the most highly stressed, while Empire Lake has few  if any
water quality exceedences even partially attributable to former
mining  activities in the area.

Notwithstanding the inhomogeneous conditions in the Galena
Subsite, the  OUFS for the study area does not consider these
natural conditions fully and  properly. As detailed below in the
specific comments:

o the public health risk assessment broadly does not
    consider the  differential conditions in the study area,
    and it frequently focuses on the worst  conditions by
    using only maximum concentrations in several calculations,
    and,

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o the ground water analysis in Appendix A-5 uses an
   incorrect statistical technique instead of the more
   conventional plume mapping to disaggregate the entire
   area.

Overall, the report, especially the public health risk
assessment, leaves the reader with the mistaken impression that
the entire Galena Subsite area has unacceptable environmental
conditions. A richer and more robust analysis would have
subdivided the OUFS study area into many subdivisions for
separate and careful analysis.


## C. Consideration of Information from the US Geological Survey

While the scope and timing of our technical review of the cited
document did not permit a careful review of all research
documents ever written about the study area, we did briefly
review three recent reports prepared by the US Geological
Survey. Broadly, the three documents do not convey the same
impression to the reader as does the report under technical
review. While we cannot fully evaluate the merits of the
apparent discrepancies between the report under review and the
three USGS reports, here are some impressions from the three
USGS reports:

Excerpts from Barker (1977):

"In 1976, the US Geological Survey made a study of the effects of
the abandoned and flooded mines and tailings piles on water
quality .... " (p 2)

"Degradation of water quality is associated with the removal of
(zinc and lead sulfides) from their reducing environment.
Oxidation of insoluble metallic-sulfide minerals in the mines
and tailings to a soluble form and subsequent solution and
hydrolysis of the soluble sulfates produces sulfuric acid and
liberates minerals. However, neutralization of the acid by
calcium carbonate in the rocks ultimately results in high
concentrations of calcium, sulfate, zinc in solution. Because of
their insolubility, most other metals are rapidly precipitated."
(p 4)

"Water in the (21) shallow wells is generally a calcium
bicarbonate type ... Only four of the wells ..... have water
with sulfate concentrations greater than 60 mg/l. Three of these
are in, or very near mines, and the other is probably in contact
with sulfide minerals....... Water from the other shallow wells
is considerably less mineralized that the mine water." (p 12)


Excerpts from Marcher et al (1984):

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"In addition to causing degradation of some stream waters, mineralized mine water might move into and contaminate water in shallow aquifers adjacent to the old mine workings; however, such movement does not appear to be widespread. Of greater significance, is the possible movement of mineralized water into the deep aquifers which are the principal source of supply for municipal and industrial use in the Tri-State district....." (p 18)


Excerpts from Spruill (1987):

"No conclusive evidence of evidence of lateral migration of water from the mines into domestic well-water supplies in the shallow aquifer was found in the study area in Kansas......" (p 1)

"In the absence of detailed sampling and site-specific drill-hole placement, it is difficult to evaluate the extent of lateral movement from the mines. However, water from shallow wells sampled for this study in the eastern area, located adjacent to and downgradient from the mines and generally in the limestone areas, did not exceed the maximum concentrations set for zinc and cadmium (table 7). Largest observed concentrations of these constituents may be the result of localized dissolution of sulfide deposits near the well. These results are consistent with the findings of Barks (1977) who reported that contaminated water was apparently confined to the mines...... (p 33)


## D. Use and Misuse of Statistics

Generally, the OUFS report uses statistical and graphical techniques poorly or incorrectly. As computers have become more powerful, statisticians have increasingly used advanced graphics programs for exploratory data analysis (Chambers et al, 1983; Cleveland, 1985). With the ability to manipulate and view multivariate data, statisticians have documented many ways in which the use of simple summary statistics (such as the arithmetic mean, the arithmetic standard deviation, the median, the geometric mean, and/or the maximum) can mislead analysts from understanding the phenomena under study. With these new techniques, statisticians have also realized many weaknesses in the traditional methods of parametric tests, nonparametric tests, and multivariate linear regression (Chambers et al, 1983; Cleveland, 1985).

In these modern times, the OUFS report uses none of these modern statistical techniques. Only Appendix A-5 considers even the most elementary properties of distributions. The human health risk assessment too often uses only the maximum concentration for a metal in the analyses when even counts, averages, and medians would have been more informative and when new graphical techniques may have revealed unexpected relationships.

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Finally, the Groundwater and Surface Water OUFS report does not consider the implications of the fact that many environmental variables have statistical distributions with long right tails, e.g., the lognormal distribution (Gilbert, 1987). Without a fundamental appreciation of the underlying statistical nature of the likely conditions in the Galena Subsite, the report's authors did not invoke techniques with sufficient power to make the proper distinctions.

## II.  SPECIFIC COMMENTS


Following the quotations or paraphrased material from the
referenced pages,  we make these comments:


### A. Section 3: Public Health and Environmental Risk Assessment


PUBLIC HEALTH ASSESSMENT

p 3-3 "In all cases the maximum contaminant concentrations
observed  in a particular medium are used ... to represent a
point of  'plausible maximum exposure'."

> Comment: While calculations based on maximum values are
> useful as a  screening tool, it is not appropriate to call
> the results "plausible  maximum exposures."


p 3-6    Table 3-2 summarizes the concentrations of total metals
in 123  private wells by reporting the average and the maximum
values.

> Comment: First, the table and accompanying text do not say
> if the 123 wells  all tap the same aquifer at the same
> depth.   Second, the maximum values for barium, cadmium,
> chromium,  copper, lead, manganese, nickel, selenium, and
> zinc all exceed  the average values by more than a factor of
> 4. This indicates that  the values for any single metal are
> highly likely to come from  underlying statistical
> distributions with long right tails, for example, a
> lognormal distribution (Gilbert, 1987). It is often
> misleading and  inappropriate to summarize such variables
> with the arithmetic mean  and maximum values, especially
> without making a histogram of  the data to investigate their
> underlying distribution(s).

p 3-6    The body of Table 3-2 shows the MCL for chromium VI, not
for   chromium III.

> Comment: The report supplies no measurements which justify
> the use of the  much lower MCL for chromium VI. Based on
> general  thermodynamic arguments, one would expect find most
> of the  chromium in the III state.


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p 3-7    Table 3-3 also shows the MCL for chromium VI, not for chromium  III.

   Comment: Same as above.


p 3-8    "A 70-kg adult ingests 2 liters...." and "a 10-kg child ingests 1  liter..." of water per day.

   Comment: While these are standard assumptions in public
   health risk  assessments, the report does not state the
   assumption used to  evaluate the ingestion of water by a
   35-kg child, one of the human  populations identified for
   analysis on p 3-4.


p 3-9 Table 3-5 shows only the maximum concentrations of dissolved  metals in surface water.

   Comment: The use of the maximum values, without any
   information about the  underlying statistical distributions
   or even the arithmetic average,  is inappropriate and likely
   misleading. Often, concentration  measurements in natural
   waters follow a lognormal distribution for  which the use of
   a maximum value as the summary statistic is  highly
   misleading. The effects that are of primary interest in this
   risk assessment are chronic, i.e. resulting from long-term
   exposure. The appropriate statistic to use, therefore, is
   one that represents the level of exposure that would be
   expected on a long-term basis.


p 3-11 "Media intakes were based on a 35-kg child swimming in a surface water body for 1 hour each day."

   Comment: First, the report has not established that children
   swim in any of the  water bodies.   Second, the report
   assumes implicitly that the 35-kg child swims  every day of
   the year. These assumptions are not realistic and are
   inconsistent with assumptions EPA has made elsewhere for
   other superfund sites. Most risk assessments conservatively
   assume that children swim a day or two each week during the
   warm summer months. The overly conservative assumption in
   this  report overstates the estimated exposure by a factor
   of 5 or more  above the conservative assumptions normally
   used to gauge  these possible exposures.   Third, the US
   EPA's Superfund Exposure Assessment Manual  (US EPA. 1986a)
   states that:    "The local recreation department may have
   detailed data  quantifying the duration and frequency of

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water use for swimming. When such locale-specific data are not available, the following national averaged figures, based on data from the Bureau of Outdoor Recreation (cite) can be applied:

o Frequency of exposure = 7 days / year

o Duration of exposure = 2.6 hours / day"

p 3-11 "..it was assumed that the (35-kg) child had an exposed surface area pf 8,800 cm2 and was 75 percent submerged in the water."

Comment: It is implausible and misleading to assume that a 35-kg child remains 75-percent submerged while swimming for an hour a day.

p 3-11 "It was assumed that this flux (of water) was 0.5 mg/cm2/hr."

Comment: The report implicitly assumes that this estimated flux of water will carry metal ions through the skin, thereby causing a dose. This is inappropriate and misleading because ionized species do not cross the skin barrier, as per these three references:

1. "Generally, only lipid-soluble, non-ionized compounds are absorbed significantly through the skin." (p 6-6; US EPA, 1986b)

2. "Very little cadmium enters the body through the skin." (p 1) and "Cadmium compounds have not been observed to cause significant health effects when exposure in by the dermal route." (p 17; ATSDR, 1987).

3. "The general population comes in frequent skin contact with lead in the form of lead-containing dusts and soil; however, only small amounts of the element will enter the body after skin contact." (p 3; ATSDR 1988) and "Dermal: Pertinent dose-effect data were not found in the available literature." (p 16; ATSDR, 1988).

p 3-11 "The daily intakes for incidental ingestion and dermal absorption (during swimming) were multiplied by the maximum dissolved concentrations of each metal in the water to obtain a daily intake of each metal."

Comment: It is inappropriate and misleading to use the maximum concentrations in these calculations, for two reasons. First, the use of the maximum is a grossly misleading summary statistic for variables having a long right tail, such as ones distributed in a lognormal distribution Second, the report has not demonstrated that any persons swim in the areas with the highest concentrations.


p 3-13 Paraphrased: Soil samples during the RI were taken downwind of the former Galena smelter, and soil samples during the FS were taken in 8 mine waste zones.

Comment: Neither the RI nor the FS has made any attempt to measure "representative" concentrations near Galena. The US EPA (i) used a "sampling dirty" sample plan designed to obtain the highest possible values, not representative values and then (ii) used these worst-worst case values in subsequent analyses. This is inappropriate, and the results may overstate otherwise "representative" or "average" analyses by as much as several orders of magnitude.


p 3-14 "A 10-kg child ingests 1 gram of contaminated soil or mine waste per day."

Comment: It is unlikely and inappropriate to model a 10-kg child (say, ages 1 through 3 years) as eating 1 gram of soil each and every day, especially dirt from the most contaminated waste piles and soils downwind of the former smelter. First, parents and caretakers of children in this age range rarely let them play in industrial waste sites. Second, rain, snow, ice, and frozen soils would limit the ingestion of soils on many days of the year, even if children happened play in the most contaminated areas. Third, recent review articles suggest that 1 gram per day for the ingestion of soils by children is a gross exaggeration. More specifically, LaGoy (1987), in a major and authoritative review, estimates that a 10-kg child ingests an average of 50 mg of soil per day and a maximum of 250 mg of soil per day from all sources, not just from heavily contaminated sites. Similarly, Paustenbach (1987) states, "When all this published information on soil ingestion is considered, the data indicate that a consensus estimate for soil ingestion by children (ages 1.5 to 3.5 years or ages 2 to 4) is about 100 mg / day. This figure

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was used by the EPA in its risk assessment and in the EPA Superfund Health Assessment Manual." Thus, the value of 1 gram / day (1,000 mg/day) assumed in this report overstates other authoritative and conservative estimates by a factor of 10 or 20 on mass alone.


p 3-15   "A 70-kg adult ingest 0.1 grams of contaminated soil or mine waste  per day."

Comment: It is unlikely and inappropriate to model the typical 70-kg adult (say, over age 18) as eating 0.1 gram (100 mg) of soil each and every day, especially dirt from the most contaminated waste piles and soils downwind of the former smelter.  First, adults do not normally spend each day in industrial waste  sites.  Second, rain, snow, ice, and frozen soils would limit the ingestion  of soils on many days of the year, even if adults happened visit the  most contaminated areas every day.  Third, recent review articles suggest that 0.1 gram per day for the  ingestion of soils by adults is a gross exaggeration. More specifically, LaGoy (1987), in a major and authoritative review,  estimates that a 70-kg adult ingests an average of 25 or 50 mg of  soil per day and a maximum of 100 mg of soil per day from all  sources, not just from heavily contaminated sites. Similarly,  Paustenbach (1987) states, "Even having considered the  contribution of poor hygiene and soil-contaminated food, the 100  mg / day figure used by CDC to estimate soil uptake by  adolescents and adults seems unlikely, and a figure of 0 to 10 mg /  day seems more reasonable and supportable." " Thus, the value of 0.1 gram/ day assumed in this report may overstate other authoritative and conservative estimates by a factor of 4 to 10 or  more on mass alone.


p 3-16 Table 3-10 is based on maximum metal concentrations.

Comment: It is inappropriate and misleading to use the maximum metal  concentrations for two reasons. First, the contractors "sampled  dirty" and thereby biased the measurements. Second, soil  concentrations usually follow an underlying statistical distribution  called the lognormal distribution for which the the maximum value  is a grossly misleading summary statistic. Because the effects that are of interest are those associated with chronic (long-term) exposures, the appropriate statistic to use is one that takes into account the central tendancy of the exposure point concentrations.


p 3-17, 18 "It was assumed for the purpose of this analysis that all fish eaten  are from locally contaminated waters."


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Comment: First, the report has not established that people catch and eat fish from the local waters, much less the most contaminated reaches. Second, the report has not established that any local fishery could support even one person who caught and ate 6.5 grams of fish each and every day for a 70-year lifetime.

p 3-18, 19 "For children, the exposure scenario consists of a 10-kg child consuming ..... 6.5 grams of fish per day."

Comment: It is inappropriate and misleading to assume that a 10-kg child (say, ages 1 through 3) eats as much fish everyday as an adult. If children eat fish in proportion to their body mass, they would ingest under 1 gram per day (Anderson et al, 1984). If children eat fish in proportion to their average daily energy expenditure (in kcal / day), the amount of fish would ingest 1 or 2 grams per day (Snyder et al, 1975). It is also appropriate to note that many children in this size and age range do not eat fish as frequently as do adults.

p 3-19 "For both children and adults, the primary pathways of exposure are ingestion of contaminated groundwater and ingestion of contaminated soil or waste."

Comment: It is important to note that swimming and eating contaminated fish are not primary pathways of exposure (even under the exaggerated assumptions on the magnitude, duration, and frequency of exposure) because the other pathways are in fact "larger" and because the analyses of the other pathways also suffer from exaggerated assumptions.

p 3-26 "At the present time, EPA considers drinking water and promulgated state water quality standards ..... to be potentially applicable or relevant and appropriate standards."

Comment: It is not clear that the Congress or the US EPA intends that the MCLs and MCLGs developed under the federal Safe Drinking Water Act are to be used as "ARARs" for ground water in mining districts, precisely because the concentrations of some or many metallic ions may exceed the MCLs or MCLGs at present and may have done so for eons.

p 3-27 "Cancer potencies were obtained from EPA's Superfund Public Health Assessment Manual."

Comment: The Agency has established the Integrated Risk Information System (IRIS Database) (US EPA, 1987) as the most authoritative source of cancer potency factors and the PHRED database for updates to the Superfund Public Health Evaluation Manual (US EPA, 1988a).


p 3-29    In Table 3-16, the report lists chromium VI.

Comment: The report has not established that any chromium VI is present in the study area. On general thermodynamic grounds, one would expect to find most of all of the metal as chromium III.


p 3-30    "A comparison of maximum contaminant concentrations observed in private wells to applicable criteria is presented in Table 2-5."

Comment: It is inappropriate to assess all the private drinking water wells on the maximum concentration for each compound, especially because the maximum concentrations may come from different wells. At a minimum, the report should include (i) a count of the number of wells measured (n=123) that exceed each individual criterion and (ii) a count of the number of wells that exceed more than one criterion simultaneously. As stated before, concentrations of metals dissolved in ground water commonly follow a lognormal statistical distribution. As a summary statistic, maximum concentrations grossly exaggerate any ion distributed according to a lognormal distribution.


p 3-33 "The common range of arsenic concentrations in soil is 1 to 50 ppm (Lindsay, 1979). Therefore, ingestion of soil containing natural background levels presents a risk comparable to that calculated for the soils and mine wastes at Galena."

Comment: First, this is the first mention in the risk assessment of natural background concentrations any metal in soil. In fact, all soils in all locations contain natural background concentrations, and every risk assessment must acknowledge their presence and focus on "elevated" concentrations that may be present from human activities. Second, as a legal and policy matter, it is not clear that the Congress and the US EPA wish to clean up any site to concentrations below those representing natural background concentrations in a locality.


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p 3-34 ".... chromium (assumed to be chromium VI) ...."

Comment: The report has not presented any evidence on the presence of chromium VI anywhere in the study area.


p 3-35 ".... chromium (assumed to be chromium VI) ...."

Comment: Same as above.


p 3-36 "First, the accuracy or reliability of the source characterization must be reviewed."

Comment: All analysts support this principle. Unfortunately, the risk assessment falls unacceptably short of the ideal for two reasons. First, the risk assessment too often uses maximum concentrations instead of better summary statistics -- or, better still, the full distributions themselves -- to assess a complicated situation. Second, the risk assessment makes no attempt to distinguish between (i) natural background concentrations and (ii) concentrations elevated by human activities. People mined ores near Galena precisely because the minerals contain(ed) high natural concentrations of certain valuable metals. While the people living near Galena may experience higher health risks than other persons living in areas of the country without the ore deposits, it is essential to distinguish naturally occurring background concentrations and risks from ones elevated by human activities.


p 3-36 "Secondly (sic), the plausibility of the exposure scenarios must be considered. The existence of an exposure pathway may be firmly documented or it may only be postulated."

Comment: All analysts support this principle. Unfortunately, the present risk assessment does not follow it. As an example of a grossly exaggerated exposure scenario, the risk assessment assumes that children weighing 10 kg (say, ages 1 through 3) will eat 1 gram of soil from the most contaminated areas in the county every day, even in the winter. This scenario is not plausible; it fails the principle stated by the authors.


p 3-38 Table 3-24 suggests that each item may underestimate or overestimate health risks.

Comment: While this may be true, the authors of the risk assessment have chosen values and scenarios that are much more likely to have overestimated the risk than to have underestimated the risk. While all risk assessments

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properly should use a conservative approach (i.e., one protective of public health), it is not proper or appropriate to choose a maximum value for every single parameter and variable in a calculation. By multiplying a series of extreme values, the authors create a scenario that is so unlikely as to be implausible and misleading.

p 3-41 "Furthermore, all potential exposure pathways have a common source -- the mine wastes."

> Comment: First, even in the narrow logic of the risk assessment, this is a false statement. For example, all of the soil samples taken during the RI and used as a partial basis of this risk assessment were taken downwind of the former smelter. Second, in the broader context, the risk assessment makes no attempt to distinguish (i) concentrations and risks attributable to natural background in an area with economic ores from (ii) concentrations and risks attributable to elevations caused by human activities.

ENVIRONMENTAL RISK ASSESSMENT

p 3-42 " A 1982 sampling program on Short Creek (EPA, 1982) investigated the influence of discharges form a fertilizer plant in Missouri ..." and "The sources of pollutants included a 70-acre fertilizer plant as well as ...."

> Comment: The rest of the environmental risk assessment does not distinguish among (i) these sources, (ii) mining sources, and (iii) natural conditions. Specifically, the report makes no mention of other point and nonpoint sources of loadings to any of the rivers, lakes, and impoundments in the study area. For example, the report does not consider the presence or absence of (i) municipal sewage treatment plants, (ii) municipal combined sewer overflows, (iii) industrial waste water discharges, (iv) agricultural runoff, or (v) other sources of (other) pollutants that can stress a biota in surface waters.

p 3-51 "KDHE stated .... that .... high nutrient loading and other water quality violations were confined largely to the Short Creek Watershed."

> Comment: The environmental risk assessment does not analyze the sources or effects of these high nutrient loadings.

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p 3-62 "The biota of Short Creek have been severely impaired by AMD. Discharges from the fertilizer plant ... and nonpoint groundwater inflow ..... add to the overall toxicity.... in Short Creek. Ammonia discharges, apparently from the fertilizer plant, exceed water quality criteria and compound problem with toxic metals. However, calcium discharges .... from the fertilizer plant increase hardness and .... reduce the toxicity effect of zinc, cadmium, and lead."

>Comment: Notwithstanding the fact that the paragraph contradicts itself, the environmental risk assessment makes no attempt to quantify the relative contributions and interactions of the materials from the several sources. Readers of the environmental risk assessment cannot determine the importance of the different sources of biological stress to the water ways.

B. Appendix A.5: Groundwater

p A-36 "Metals concentrations in groundwater can be used to separate the private wells into two groups -- one with minimal relationship with groundwater in the mine workings and another group which can be related directly to groundwater in the mine workings. The first group includes ground water that is described alternatively as having background, baseline, or threshold metals concentrations, and the second as affected, impacted, or anomalous metals concentration ranges."

>Comment: The conceptual distinction made here between background concentrations and anthropogenic elevations of concentrations does not appear in the public health risk assessment.

p A-36 "The ability to separate the water quality of private wells into threshold and anomalous concentration ranges .... leads to a probabilistic or statistical analysis rather than plume definition..... Frequency distributions of metals concentrations is a scientifically rigorous, objective statistical technique used .... to separate threshold (peripheral mineralization) from anomalous (potential ore deposit drilling targets) metal concentrations. The technique is a graphical statistical technique plotting metal concentration (ug/l) versus cumulative percent of samples...... A single group of metal concentrations ... will plot as a straight line on the cumulative frequency distribution graph. ......." (with continuing sentences).

>Comment: First, the authors offer no literature citations to support these assertions. Second, prima facie, the assertion that: "A single group of metal concentrations ... will plot as a straight line on the cumulative

frequency distribution graph. ......." is false. See, for
example, Hastings and Peacock (1974). In general, with the
exception of the uniform probability density function, all
probability density functions (for single statistical
populations) plot as a rising curve with an asymptote of 1
as the random variate tends to its upper bound. Third, in
Figures A-12 through A-16 for total lead, total zinc,
dissolved zinc, total cadmium, and sulfate, respectively,
the authors place great emphasis on the power of two
fitted, linear regression lines to distinguish between two
statistical distributions which they hypothesize as
underlying the field data. Unfortunately, the method is
wrong and misleading.

While the proof that the report's technique is wrong in
general presupposes a strong foundation in theoretical
statistics, it is easy to demonstrate a counter example in
which the report's technique creates a counterfactual
conclusion. Based on the data and regressions lines shown
in Figure A-12 from Appendix A.5 and reproduced as Exhibit
1 with this technical review, the authors of the original
report conclude that the values below the breakpoint (at
7.9 ug/l of total lead) come from one statistical
distribution and that the values above the breakpoint come
from a second distribution. They also conclude that the two
underlying distributions have means that are significantly
different at the 99 percent confidence level (see p A-38 of
the report). They further conclude that "there is only only
one in 100 analyses that could be misclassified in the two
groups" (p A-38).

Contrast the claims of the authors of the original report
with the values and fitted lines in shown in Exhibit 2, as
prepared for this technical review. Using the same logic as
in Appendix A.5, one would conclude that the values come
from two underlying statistical distributions that have
different means at some high degree of confidence. However,
the 20 values plotted in Exhibit 2 come from a single
lognormal distribution!

Many environmental variables are distributed in lognormal
distributions (Gilbert, 1987), a distribution typically
having a long right tail. As such, lognormal distributions
commonly have cumulative plots that rise strongly from the
origin and then eventually asymptote at one as the random
variate reaches it upperbound. A naive person might try to
fit two straight lines to the cumulative plot in an effort
to understand the data, but it would be wrong to conclude
from the exercise that the values come from two underlying
distributions. The values come from a single statistical
population simulated by Monte Carlo technique (see, for
example, Morgan, 1984, or Rubinstein, 1981) and any
inference that the two fitted straight lines represent two
underlying phenomena is flat wrong.

Exhibit 1
Frequency Distribution
Cited in Appendix A-5: Groundwater
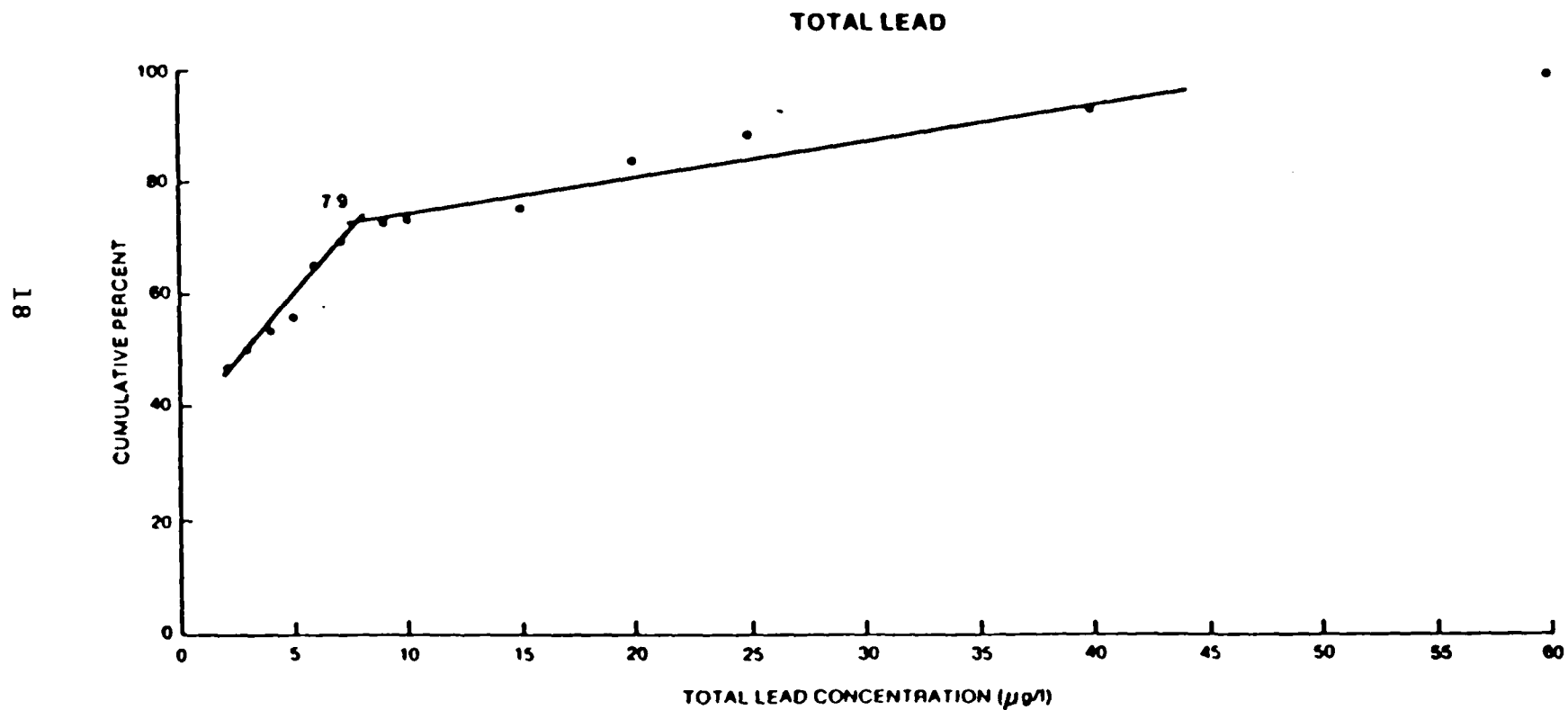
**TOTAL LEAD**



FIGURE A-12
FREQUENCY DISTRIBUTION FOR
TOTAL LEAD IN GROUNDWATER
FROM PRIVATE WELLS
CHEROKEE COUNTY, KANSAS
GALENA SUBSITE — OUFS
GROUNDWATER/SURFACE WATER

Exhibit 2
Cumulative Frequency Distribution for
Synthetic Data Simulated from a Single Lognormal Distribution

Total Concentration of Metal, (μg/l)

Cumulative Fraction
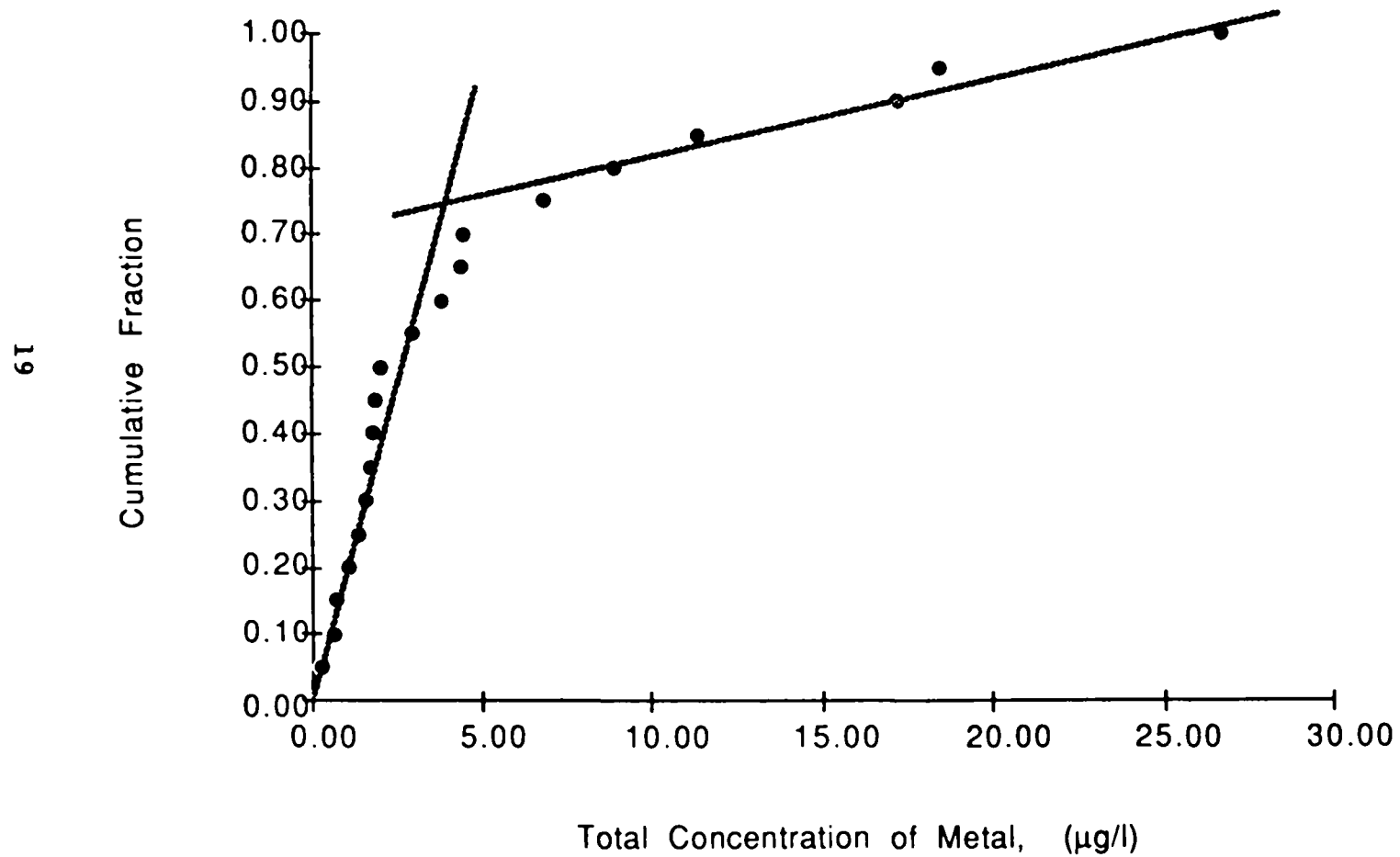
p A-45 "In summary, the statistical evaluation of the shallow groundwater  private well water quality defines two significantly different groups.  One group, the threshold group with low concentrations, is  probably related to random natural mineralization in the subsite.  The other group, the anomalous group with higher concentrations,  is statistically related to the mine workings...."

> Comment: First, note the use of "probably" in the second sentence. The  authors of the original report understand that they do not have a  causal model.  Second, and more importantly, the method is wrong in that it can  create distinctions where none are present.

C. Appendix A.7: Groundwater-Surface Water Interaction

p A-90, 91 "To evaluate the changes to water quality occurring in the Galena  watersheds, it is necessary to establish water quality in areas  tributary to the subsite but unaffected by the surrounding mine  wastes and subsurface geochemical reactions occurring in the  subsite." and  "Groundwater Quality. The analysis to support the groundwater  concentrations have been previously discussed in Section A-5."

> Comment: To the extent that the model developed in this section relies on the  faulty analysis in Appendix A-5, the conclusions in this section are  also faulty.

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February 26, 1988.

**AMAX** Research & Development Center

5950 McIntyre Street • Golden, Colorado 80403-7499

(303) 273-7200

## INTEROFFICE MEMORANDUM

January 27, 1988

Subject: Galena Samples from Kansas Superfund Site (81222)

To:     Ken Paulsen

From:   D. Malhotra

cc: S. Armstrong
    A.K. Bhasin
    P. Keppler
    R.M. Rowe

## INTRODUCTION

As per your request, preliminary test work was performed to evaluate the potential of recovering lead and other heavy minerals from waste rock and "chat" samples obtained from the Kansas Superfund site. This IOM summarizes the results of the study.

## SUMMARY

Bench-scale exploratory test work was performed to determine if heavy metals could be recovered by mineral processing techniques from samples collected from the Cherokee County, Kansas Superfund site.

Preliminary results indicate that 44 to 84 percent of lead and 70 to 98 percent of zinc can be recovered in the flotation concentrate from these samples. The flotation tailings would be nonhazardous as long as the lead values in them are less than 0.3% Pb.

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# RESULTS AND DISCUSSION

Twelve samples from the Kansas Superfund site were analyzed for heavy metals at the AMAX R&D Center. The results are summarized in Appendix A.

The following four samples were selected for metallurgical test work:

| Sample No. | Sample Designations | % Pb | % Zn |
|---|---|---|---|
| 2 | PRP-2 | 0.423 | 0.80 |
| 9 | Area 1, Station 7 | 1.11 | 0.242 |
| 12 | Area 5, South side | 0.0655 | 1.72 |
| 6 | PRP.6 | 0.08 | 0.265 |

Preliminary gravity and flotation tests were performed to evaluate the potential of recovering heavy metals from these samples. EP toxicity tests were performed on 12 feed samples and selected flotation-tailing samples to determine what samples would have to be classified as hazardous material. The results are discussed below.

## Gravity Tests

Sample No. 9 (Sample Area No. 1, Station No. 9) was sized and a sink-float test was performed on 28 X 100-mesh fraction assaying 1.08% Pb and 0.34% Zn. The heavy liquid used for the test was acetylene tetrabromide which has a specific gravity of 2.96. The results are summarized in Appendix B. The sink fraction recovered 2.9, 75.5, and 94.5 percent of weight, lead and zinc, respectively, and assayed 30.3% Pb and 12.2% Zn. The float fraction assayed 0.29% Pb and 0.02% Zn.

These results indicate that it is theoretically possible to recover lead and zinc values from the sample by gravity. However, due to the lack of availability of a large sample, the PRP-2 sample (assaying 0.368% Pb and 0.762% Zn) was ground and tabled for a large-scale test. Test results, presented in Appendix B, indicate that only 20.3 and 55.4 percent of lead and zinc values were recovered in concentrate which contained 2.1% of the original weight of feed. The concentrate assayed 3.49% Pb and 19.7% Zn. It appears from this data that additional testing would be needed to determine if gravity concentration methods would recover heavy minerals from a majority of the samples.

## Flotation Tests

The samples stored at the Kansas Superfund site are waste rock and tailings from a milling operation which processed sulfide ores of lead and zinc several decades ago. Our past experience with similar projects indicates that any sulfides exposed to air

and moisture would have transformed to oxides during this period. Since the main objective of the reprocessing study is to reduce the concentration of toxic metals and sulfide and acid forming capabilities, the process should be able to recover a concentrate containing both oxides and sulfides of heavy metals.

The flotation process evaluated consisted of recovering sulfides in the first step followed by sulfidization of oxides and flotation of these sulfidized values. The flotation procedure and reagents utilized are given in Figure 1. The test results are summarized in Table 1. The results indicate that 44 to 84 percent of lead and 70 to 98 percent of zinc can be recovered in the concentrate containing only 8 to 14 percent of the original feed material. It is important to note that these results were obtained despite no attempt to optimize process variables. Hence, it is reasonable to conclude that it is possible to recover heavy metals from these samples by mineral processing techniques.

## Toxicity Tests

EP extraction tests were performed on the twelve feed samples and the selected flotation tailing samples. The test results are given in Appendix D and summarized for Pb in Table 2 and Figure 2. The results indicate that Pb levels in leachate meet the EPA requirements of $\leq 5$ ppm as long as the Pb levels in the feed are less than 0.3%. However, additional extraction tests should be performed to better determine this relationship.

D. Malhotra

/kf

| REAGENTS | ORE | TEST CONDITIONS |
|---|---|---|
| | ↓ | |
| | **GRIND** | 60% solids |
| | | Time = variable |
| | ↓ | |
| **Lime to pH=8.5** | | |
| **1.0 lb/t CuSO₄** | **CONDITION** | 5 minutes |
| **0.5 lb/t Xanthate 350** | | 60% solids |
| **MIBC** | ↓ | |
| | **FLOTATION** → 3 timed concentrates | Time = 2, 2 and 4 minutes concentrates |
| | ↓ | 35% solids |
| | **TAILING** | |
| | ↓ | |
| | **FILTER** | |
| | ↓ | |
| **Lime to pH=8.5** | | |
| **2 lb/t NaHS** | **CONDITION** | |
| **0.5 lb/t Xanthate 350** | | |
| **MIBC** | ↓ | |
| | **FLOTATION** → 2 timed concentrates | Time = 4 and 4 minutes concentrates |
| | ↓ | 35% solids |
| | **TAILING** | |

Figure 1.  General Flotation Test Procedure

TABLE 1.   SUMMARY OF FLOTATION TEST RESULTS FOR KANSAS GALENA SAMPLES

| SAMPLE | GRIND % + 100 mesh | GRADE % | | | | | | RECOVERY % | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Feed | | Conc. | | Tailing | | Wt | Pb | Zn |
| | | Pb | Zn | Pb | Zn | Pb | Zn | | | |
| Area 1, Station 7 | 67.2 | 1.10 | 0.246 | 8.15 | 2.73 | 0.46 | 0.02 | 8.3 | 61.7 | 92.5 |
| Area 5, South Side | 35.3 | 0.07 | 1.74 | 0.33 | 8.95 | 0.03 | 0.61 | 13.6 | 63.3 | 70.0 |
| Area 5, South Side | 57.4 | 0.07 | 1.88 | 0.43 | 12.10 | 0.03 | 0.60 | 11.1 | 63.9 | 71.6 |
| PRP-2 | 59.3 | 0.46 | 0.88 | 3.85 | 8.51 | 0.08 | 0.02 | 10.1 | 84.4 | 97.9 |
| PRP-6 | 57.6 | 0.08 | 0.265 | 0.28 | 1.93 | 0.05 | 0.05 | 12.1 | 44.0 | 84.5 |

Flotation Time: 16 minutes

## TABLE 2. EP TOXICITY TEST RESULTS

| SAMPLE | FEED, % Pb | EP EXTRACTION, ppm Pb |
|---|---|---|
| PRP1 | 0.242 | <2.36 |
| PRP2 | 0.423 | 3.8 |
| PRP3 | 0.212 | <2.36 |
| PRP4 | 0.325 | <2.36 |
| PRP5 | 0.177 | <2.36 |
| PRP6 | 0.080 | <2.36 |
| PRP7 | 0.369 | 12 |
| PRP8 | 0.060 | <2.36 |
| Area 1, South End | 0.047 | <2.36 |
| Area 1, Station 7 | 1.11 | 177 |
| Area 1, Station 7 Flotation Tailing | 0.46 | 9.3 |
| Area 5, South Side Flotation Tailing | 0.03 | <2.36 |
| PRP6 Flotation Tailing | 0.05 | <2.36 |

Figure 2. Relationship between Pb in Leachate and Feed Samples

# APPENDIX A

## CHEMICAL ANALYSIS OF SAMPLES FROM
## CHEROKEE COUNTY, KANSAS SUPERFUND SITE

# AMAX

## ANALYTICAL REPORT

**EXTRACTIVE RESEARCH & DEVELOPMENT, INC.**
5950 McINTYRE STREET, GOLDEN, COLORADO 80401
303-279-7636

JOB NUMBER **82449**

DATE SUBMITTED 8/14/87
SUBMITTED BY Boyd
COPIES TO: Ken Paulson

DATE COMPLETED ___
WORKING ___
PLACE NUMBER ___

DEPT NO ___

SUBMITTER'S COMMENTS Galena, KS coarse samples
SAMPLE PREP: YES ☐ NO ☐

DESIRED ACCURACY See attached memo

ROUTINE ☐   EXPEDITE ☐   AUTHORIZED BY ___

| SAMPLE IDENTIFICATION | ppm As | EST | Fe | EST | Ni | EST | Cu | EST | Zn | EST | Mn | EST | SAMPLE MATRIX/COMPOSITION (e.g. pH MAJOR IONS) Pb Cd, Au etc Hg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1  | 1PRP | 3.5 | | | | | | | | | | | | |
| 2  | 2PRP | 4. | | | | | | | | | | | | |
| 3  | 3PRP | 5.5 | | | | | | | | | | | | |
| 4  | 4PRP | 28. | | | | | | | | | | | | |
| 5  | 5PRP | 21. | | | | | | | | | | | | |
| 6  | 6PRP | 5.5 | | | | | | | | | | | | |
| 7  | 7PRP | 6.5 | | | | | | | | | | | | |
| 8  | 8PRP | 5. | | | | | | | | | | | | |
| 9  | Area1 station7 | 7. | | | | | | | | | | | | |
| 10 | Area1 south End | 6. | | | | | | | | | | | | |
| 11 | Area5 N. side | 5. | | | | | | | | | | | | |
| 12 | Area5 S. side | 5. | | | | | | | | | | | | |
| 13 | Bruster Mine Chat | 6. | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | AT 8/11/87 |
| 16 | | | | | | | | | | | | | | PP # 33-Et |
| 17 | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | |

*ICP results attached*

| ANALYST'S SIGNATURE(S) | CODE | DATE | DETER | METHOD | COMMENTS |
|---|---|---|---|---|---|
| NV | 42 | 8/21 | As | Furn AA | |
| | | | | | |
| | | | | | |
| | | | | | |

| | SAMPLE | AU | ... |
|---|---|---|---|
| 1 | 1FRF | 0.001 | 0.970 |
| 2 | 2FRF | 0.001 | 0.800 |
| 3 | 3FRF | 0.001 | 0.795 |
| 4 | 4FRF | 0.001 | 0.525 |
| 5 | 5FRF | 0.001 | 0.350 |
| 6 | 6FRF | 0.003 | 0.265 |
| 7 | 7FRF | 0.001 | 0.417 |
| 8 | 3FRF | 0.001 | 1.02 |
| 9 | A157 | 0.001 | 0.242 |
| 10 | A13 | 0.001 | 0.184 |
| 11 | A5N | 0.001 | 1.31 |
| 12 | A5S | 0.002 | 1.72 |
| 13 | B MINE | 0.001 | 1.06 |
| 14 | 13R | 0.001 | 0.920 |

RESULTS ARE REPORTED IN PERCENT
O.H. LAT.FUSSION
SAMPLES WERE NOT DILUTED FOR SI(FUSSION NOT COMPLETE)
RFTS
17-AUG-87 11:53:38

**AURO-TECH ASSAYING • 5158 PARFET ROAD • WHEAT RIDGE, CO 80033 • (303)431-4563 • (303)421-2062**

AMAX Research & Development
5950 McIntyre Street
Golden, CO  80403

ATTN:  Vo

August 18, 1987


Dear Vo:
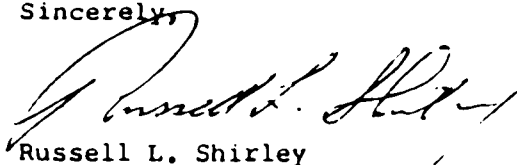
Analyses report for samples submitted by you on August 11, 1987.

Project 62     ATA #2629     13 pulps for AuAg fire assay.

AMAX Project #82449     D.P. #33-87.

| ATA # | AMAX R & D # | Au oz/ton | Ag oz/ton |
|-------|--------------|-----------|-----------|
| 2629-1 | 82449-1 | (0.002 | 0.155 |
| -2 | -2 | (0.002 | 0.229 |
| -3 | -3 | (0.002 | 0.221 |
| -4 | -4 | (0.002 | 0.069 |
| -5 | -5 | (0.002 | 0.191 |
| -6 | -6 | (0.002 | 0.210 |
| -7 | -7 | (0.002 | 0.260 |
| -8 | -8 | (0.002 | 0.124 |
| -9 | -9 | (0.002 | (0.002 |
| -10 | -10 | (0.002 | 0.128 |
| -11 | -11 | (0.002 | 0.120 |
| -12 | -12 | 0.005 | 0.136 |
| -13 | -13 | (0.002 | 0.091 |

Sincerely,

Russell L. Shirley

RLS:sf

# APPENDIX B

## GRAVITY TEST RESULTS

CASE: KANSAS GALENA TEST PRP-2, TABLE TEST

MATERIAL BALANCE

INPUT DATA
----------

|  | WEIGHT | PB | ZN |
|---|---|---|---|
| PAN 1,2,3 | 39.600 | 3.4900 | 19.7000 |
| PAN 4 | 114.100 | 1.0200 | 0.5500 |
| PAN 5 | 444.200 | 0.1180 | 0.2230 |
| PAN 6-9 | 1251.100 | 0.2980 | 0.3730 |
| TOTAL | 1849.000 |  |  |

| CALC HEAD |  | 0.368 | 0.762 |
|---|---|---|---|
| ASSAY HEAD |  | 0.461 | 0.877 |
| PERCENT DIFF |  | 20.244 | 13.134 |

PERCENT DISTRIBUTION
--------------------

| PAN 1,2,3 | 2.142 | 20.329 | 55.383 |
|---|---|---|---|
| PAN 4 | 6.171 | 17.119 | 4.455 |
| PAN 5 | 24.024 | 7.710 | 7.032 |
| PAN 6-9 | 67.664 | 54.841 | 33.130 |
| TOTAL | 100.000 | 100.000 | 100.000 |

CUMULATIVE PERCENT DISTRIBUTION
-------------------------------

| PAN 1,2,3 | 2.142 | 20.329 | 55.383 |
|---|---|---|---|
| PAN 4 | 8.313 | 37.449 | 59.838 |
| PAN 5 | 32.336 | 45.159 | 66.870 |
| PAN 6-9 | 100.000 | 100.000 | 100.000 |

CUMULATIVE ASSAY IN CONCENTRATE
-------------------------------

| PAN 1,2,3 |  | 3.4900 | 19.7000 |
|---|---|---|---|
| PAN 4 |  | 1.6564 | 5.4839 |
| PAN 5 |  | 0.5135 | 1.5754 |
| PAN 6-9 |  | 0.3677 | 0.7618 |

CUMULATIVE ASSAY IN TAILS
-------------------------

| PAN 1,2,3 | 1809.400 | 0.2993 | 0.3473 |
|---|---|---|---|
| PAN 4 | 1695.300 | 0.2508 | 0.3337 |

## KANSAS GALENA HEAVY LIQUIDS TEST: SAMPLE AREA NO. 1, STATION NO. 7

|  | Sink-Float Test 28 x 100 Mesh |
|---|---|
| **Feed** | |
| %Pb | 1.08 |
| %Zn | 0.34 |
| **Concentrate** | |
| %Pb | 30.3 |
| %Zn | 12.2 |
| **Recovery** | |
| %weight | 2.9 |
| %Pb | 75.5 |
| %Zn | 94.5 |
| **Tailing** | |
| %weight | 97.1 |
| %Pb | 0.29 |
| %Zn | 0.02 |

**APPENDIX C**

**FLOTATION TEST DATA**

**APPENDIX D**

EP TOXICITY TEST RESULTS

# AMAX

**EXTRACTIVE RESEARCH & DEVELOPMENT, INC.**
5950 McINTYRE STREET, GOLDEN, COLORADO 80401
303-279-7636

## ANALYTICAL REPORT

82648

DATE SUBMITTED _10-26-87_
DATE COMPLETED _12-1-87_
WORKING PLACE NUMBER _8122_

JOB NUMBER
SUBMITTED BY _N. Johnson_ ext _295_
COPIES TO: _D. Malhotra_
_S. Armstrong_

DEPT NO _____

SUBMITTER'S COMMENTS _EP Toxicity Tests_     SAMPLE PREP   YES ☐   NO ☑
_Liquor Samples_

DESIRED ACCURACY _____

ROUTINE ☐     EXPEDITE ☐     AUTHORIZED BY _____

| SAMPLE IDENTIFICATION | As ppm | E S T | Ba ppm | E S T | Cd ppm | E S T | Cr ppm | E S T | Pb ppm | E S T | Hg ppm | E S T | SAMPLE MATRIX/COMPOSITION (e.g. pH, MAJOR IONS, ELEMENTS ETC.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 Area 1 St 7 Feed | <1 | | | | | | | | | | <.002 | | H₂O/Acetic |
| 2 Area 1 St 7 Tails | <1 | | | | | | | | | | <.002 | | Acid |
| 3 Area 5 S. Side Tail | <1 | | | | | | | | | | <.002 | | |
| 4 | | | ← ICP results are attached → | | | | | | | | | | |
| 5 | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | |
| 9 | Se ppm | | Ag ppm | | | | | | | | | | |
| 10 | | | | | | | | | | | | | |
| 11 As above | <.1 | | <.1 | | | | | | | | | | |
| 12 | <.1 | | <.1 | | | | | | | | | | |
| 13 | <.1 | | <.1 | | | | | | | | | | |

| ANALYST'S SIGNATURE(S) | CODE | DATE | DETER. | METHOD | COMMENTS |
|---|---|---|---|---|---|
| _[signature]_ | 16 | 10/30/87 | ICP | MTE+W | 5% HNO₃ - 20X |
| NV | 42 | 11-19 | As As Se | furnace AA | |
| BND | 68 | 12-1-87 | Hg | Cold Vapor A.A. STD. ADD. | Book XIV PAGE 2 |

82648 EF TOX. SOLUTIONS

(RESULTS ARE CORRECTED FOR DILUTION)

DATE OF ANALYSIS:   30 - OCT - 87

| | SAMPLE | AS | AL | BA | BE | CA | CD | CO1 |
|---|---|---|---|---|---|---|---|---|
| 1 | A1FEED | < 0.840 | < 1.60 | < 0.026 | < 0.012 | < 0.014 | < 0.096 | < 0.160 |
| 2 | A1TAIL | < 0.840 | < 1.60 | 0.1 | < 0.012 | 12 | < 0.096 | < 0.150 |
| 3 | ASTAIL | < 0.840 | < 1.60 | < 0.026 | < 0.012 | 358 | 0.81 | < 0.150 |

| | SAMPLE | CR | CU | FE1 | MG | MN | MO1 | NI1 |
|---|---|---|---|---|---|---|---|---|
| 1 | A1FEED | < 0.080 | < 0.092 | 31.0 | < 1.36 | 1.9 | < 0.080 | < 0.286 |
| 2 | A1TAIL | 0.09 | 0.24 | 0.32 | < 1.36 | 0.96 | < 0.080 | < 0.286 |
| 3 | ASTAIL | 0.26 | 1.9 | 5.1 | 93.3 | 1.6 | < 0.080 | < 0.286 |

| | SAMPLE | PB | V | ZN2 | W |
|---|---|---|---|---|---|
| 1 | A1FEED | 62.0 | < 0.080 | 2.8 | 0.98 |
| 2 | A1TAIL | 9.3 | < 0.080 | 0.40 | < 0.720 |
| 3 | ASTAIL | < 2.36 | < 0.080 | 235 | 1.1 |

RESULTS ARE IN PPM

JOB  MTE+W #2
30-OCT-87 18:45:38
RPT2

# ANALYTICAL REPORT

**82837**

## AMAX
**EXTRACTIVE RESEARCH & DEVELOPMENT, INC.**
5950 McINTYRE STREET, GOLDEN, COLORADO 80401
303-279-7636

DATE SUBMITTED: 11-17-87
DATE COMPLETED: 12-1-87
WORKING PLACE NUMBER: 8/2 2 2
DEPT NO: 500

JOB NUMBER
SUBMITTED BY: N. Jameson EXT 295
COPIES TO: R. Malhotra
S. Armstrong

SAMPLE PREP   YES ☐   NO ☑

SUBMITTER'S COMMENTS: EP Toxicity Tests

DESIRED ACCURACY:

ROUTINE ☐   EXPEDITE ☑

AUTHORIZED BY:

| SAMPLE IDENTIFICATION | As ppm | EST | Se ppm | EST | Ag ppm | EST | Cr | EST | Pb | EST | Hg ppm | EST | SAMPLE MATRIX/COMPOSITION (10 g pH MAJOR IONS ELEMENTS ETC.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 PRP 1 | <.1 | | <.1 | | <.1 | | | | | | <.002 | | H₂O/Acetic Acid |
| 2  2 | <.1 | | <.1 | | <.1 | | | | | | <.002 | | |
| 3  3 | <.1 | | <.1 | | <.1 | | | | | | <.002 | | |
| 4  4 | <.1 | | <.1 | | <.1 | | | | | | <.002 | | |
| 5  5 | <.1 | | <.1 | | <.1 | | | | | | <.002 | | |
| 6  6 | <.1 | | <.1 | | <.1 | | | | | | <.002 | | |
| 7  7 | <.1 | | <.1 | | <.1 | | ICP attached | | | | <.002 | | |
| 8  8 | <.1 | | <.1 | | <.1 | | | | | | <.002 | | |
| 9 Area 1 South End | <.1 | | <.1 | | <.1 | | | | | | <.002 | | |
| 10 Brewster Mine | <.1 | | <.1 | | <.1 | | | | | | <.002 | | |
| 11 Area 1 Station 7 | <.1 | | <.1 | | <.1 | | | | | | <.002 | | |
| 12 PRP 6 Tails | <.1 | | <.1 | | <.1 | | | | | | <.002 | | |
|  | Se above | | Se above | | Ba | | Cd | | | | | | |
| As above | | | | | | ICP attached | | | | | | | |

| ANALYST'S SIGNATURE(S) | CODE | DATE | DETER | METHOD | COMMENTS |
|---|---|---|---|---|---|
| BND | 68 | 12-1-87 | Hg | Cold Vapor A.A. Std. Add. | Book XIV p22 |
| NV | 42 | 11-19 | Ag As Se | Furnace AA | |
| 2/8 | 16 | 11/25 | Cr, Pb, & Cd | ICP METw #2 | Most solutions contain colloidal and/or ppt. Fe |

ORIGINATOR REMOVE CARBONS RETAIN THIRD PINK SHEET FOR YOUR FILES

82837  EP TOXICITY

(RESULTS ARE CORRECTED FOR DILUTION)

DATE OF ANALYSIS:   25 - NOV - 87

| SAMPLE | AS | AL | BA | BE | CA | CD | CO1 |
|--------|------|------|------|------|------|------|------|
| 1 PRP 1 | 1.4 | < 1.60 | 0.26 | < 0.012 | 5.2 | 0.1 | < 0.160 |
| 2 PRP 2 | < 0.840 | < 1.60 | 0.35 | < 0.012 | 5.0 | 0.1 | < 0.160 |
| 3 PRP 3 | < 0.840 | < 1.60 | 0.21 | < 0.012 | 3.7 | < 0.096 | < 0.160 |
| 4 PRP 4 | 1.9 | < 1.60 | 0.54 | < 0.012 | 7.6 | 0.2 | < 0.160 |
| 5 PRP 5 | < 0.840 | 3.6 | 0.24 | < 0.012 | 18 | < 0.096 | < 0.160 |
| 6 PRP 6 | 1.2 | < 1.60 | 1.3 | < 0.012 | 32.3 | 0.1 | < 0.160 |
| 7 PRP 7 | < 0.840 | < 1.60 | 0.21 | < 0.012 | 8.8 | 0.1 | < 0.160 |
| 8 PRP 8 | < 0.840 | 1.9 | 0.1 | < 0.012 | 3 | < 0.096 | < 0.160 |
| 9 A1SEND | 0.50 | 4.5 | 0.2 | < 0.012 | 7 | < 0.096 | 0.2 |
| 11 A1 S7 | 1.0 | 2.4 | 0.09 | < 0.012 | 19 | < 0.096 | < 0.160 |
| 12 6TAILS | < 0.840 | < 1.60 | 0.70 | < 0.012 | 34.9 | < 0.096 | < 0.160 |

| SAMPLE | CR | CU | FE1 | MG | MN | MO1 | NI1 |
|--------|------|------|------|------|------|------|------|
| 1 PRP 1 | < 0.080 | < 0.092 | 164 | < 1.36 | 4.6 | < 0.080 | 0.68 |
| 2 PRP 2 | < 0.080 | < 0.092 | 237 | < 1.36 | 4.0 | < 0.080 | 0.51 |
| 3 PRP 3 | < 0.080 | < 0.092 | 178 | < 1.36 | 3.0 | < 0.080 | < 0.286 |
| 4 PRP 4 | 0.53 | < 0.092 | 38.2 | 3.3 | 3.6 | < 0.080 | 0.67 |
| 5 PRP 5 | < 0.080 | < 0.092 | 84.7 | 3.9 | 3.4 | < 0.080 | < 0.286 |
| 6 PRP 6 | < 0.080 | < 0.092 | 177 | < 1.36 | 5.4 | < 0.080 | 0.45 |
| 7 PRP 7 | < 0.080 | < 0.092 | 144 | 2.7 | 3.0 | < 0.080 | < 0.286 |
| 8 PRP 8 | 4.7 | < 0.092 | 193 | < 1.36 | 3.0 | < 0.080 | 0.46 |
| 9 A1SEND | < 0.080 | < 0.092 | 189 | 4.0 | 4.4 | < 0.080 | 1.00 |
| 11 A1 S7 | < 0.080 | < 0.092 | 90.2 | 1.7 | 3.0 | < 0.080 | 0.42 |
| 12 6TAILS | < 0.080 | < 0.092 | 0.2 | 1.4 | 1.2 | < 0.080 | < 0.286 |

| SAMPLE | PB | V | ZN2 | W |
|--------|------|------|------|------|
| 1 PRP 1 | < 2.36 | < 0.080 | 2.6 | 1.1 |
| 2 PRP 2 | 3.8 | < 0.080 | 3.0 | 1.1 |
| 3 PRP 3 | < 2.36 | < 0.080 | 3.4 | 0.83 |
| 4 PRP 4 | < 2.36 | < 0.080 | 16 | 0.70 |
| 5 PRP 5 | < 2.36 | < 0.080 | 13 | 0.79 |
| 6 PRP 6 | < 2.36 | < 0.080 | 14 | 1.1 |
| 7 PRP 7 | 12 | < 0.080 | 11 | 1.0 |
| 8 PRP 8 | < 2.36 | < 0.080 | 7.4 | 0.95 |
| 9 A1SEND | < 2.36 | < 0.080 | 5.3 | 0.99 |
| 11 A1 S7 | 177 | < 0.080 | 4.9 | 0.99 |
| 12 6TAILS | < 2.36 | < 0.080 | 9.3 | 0.80 |

RESULTS ARE IN PPM
ONLY REQUESTED ELEMENTS ARE CALIBRATED
JOB NTE + W 42
25-NOV-87 13:44:07

# APPENDIX B


# BOND'S WORK INDEX DETERMINATION FOR
# A COMPOSITE SAMPLE

Project Name & Number _Kansas Galena_          Date _3-1-88_
Sample: _Composite_                  Tested By _P. Armstrong_
Test Number: _#1_

## Grindability Tests

**Purpose:** To determine ball mill grindability of the test sample in terms of a Bond Work Index Number.

**Procedure:** The equipment and procedure duplicate the Bond Method for determining the ball mill work indices.

**Test Conditions:** Desired Mesh of Grind: _35_ Mesh
Weight of undersize needed for _250_% Circulating load _322.3_ gms. (Y)
Weight % of undersize in mill feed _29.7_% (X) (from Screening)

### Test Results:

| Cycle Number | Feed Grams A | Undersize Grams In Feed B | Undersize Grams To be Produced C | Mill Revs. D | Wt. of Undersize E | Mill Production Total Net F | Mill Production Per Rev. G |
|---|---|---|---|---|---|---|---|
| 1 | 1128.0 | 335.0 | ∅ | ∅ | 383.2 | 48.2 | ∅ |
| 2 | 383.2 | 113.8 | 208.5 | 60 | 263.2 | 149.5 | 2.49 |
| 3 | 263.2 | 78.2 | 244.1 | 98 | 275.4 | 197.2 | 2.01 |
| 4 | 275.4 | 81.8 | 240.5 | 120 | 310.2 | 228.4 | 1.90 |
| 5 | 310.2 | 92.1 | 230.2 | 121 | 290.8 | 198.7 | 1.64 |
| 6 | 290.8 | 86.4 | 235.9 | 144 | 315.2 | 228.8 | 1.59 |
| 7 | 315.2 | 93.6 | 228.7 | 144 | 323.6 | 230.0 | 1.60 |

Avg. of last three = _1.61_

Avg. of 3 Mill Feed S.A.

| Tyler Mesh | Weight On | % Wt. On | Cum % Wt. On | Cum. Passing |
|---|---|---|---|---|
| 8 | 37.4 | 16.7 | 16.7 | 83.3 |
| 10 | 33.5 | 15.0 | 31.7 | 68.3 |
| 14 | 27.0 | 12.0 | 43.7 | 56.3 |
| 20 | 24.2 | 10.8 | 54.5 | 45.5 |
| 28 | 18.7 | 8.3 | 62.8 | 37.2 |
| 35 | 16.7 | 7.5 | 70.3 | 29.7 |
| -35 | 66.6 | 29.7 | 100 | |
| 65 | | | | |
| 100 | | | | |
| - | | | | |
| Total | 224.1 | | | |

Ground Product

| Tyler Mesh | Weight On | % Wt. On | Cum. % Wt. On | Cum. Passing |
|---|---|---|---|---|
| 48 | 51.2 | 25.8 | 25.8 | 74.2 |
| 65 | 32.4 | 16.4 | 42.2 | 57.8 |
| 100 | 20.6 | 10.4 | 52.6 | 47.4 |
| 150 | 19.0 | 9.6 | 62.2 | 37.8 |
| 200 | 13.4 | 6.8 | 69.0 | 31.0 |
| 270 | 9.9 | 5.0 | 74.0 | 26.0 |
| 400 | 9.4 | 4.7 | 78.7 | 21.3 |
| -400 | 42.2 | 21.3 | 100 | |
| Total | 198.1 | | | |

A1 = Avg. Wt. in gms. of (3) 500cc samples
A2 = E1; A3 = E2...etc.
Y = A1 divided 3.5 for 250% circulating load
X = Avg. wt. on of undersize from screening

B = A multiplied by X
C = Y minus B
D1= C1 divided by 3.5
D2= C2 divided by G1...etc.
E = Wt. of product
F = E minus B

$$W_i = \frac{44.5}{(P_i)^{0.23}(G_{bp})^{0.82}\left(\frac{10}{\sqrt{P}} - \frac{10}{\sqrt{F}}\right)}$$
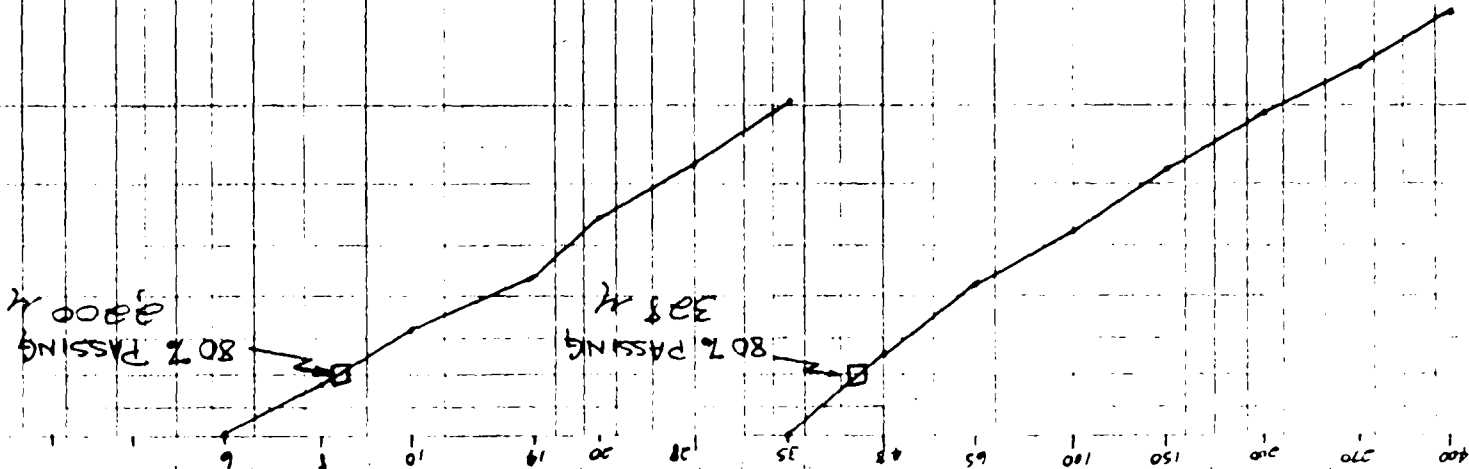
$P_i$ = Tested size, Microns (35M) = 425 $\mu m$

$G_{bp}$ = Ball Mill Grindability (gm/Rev) Avg = 1.61

$P$ = 80% Passing Product Microns = 338

$F$ = 80% Passing Feed Microns = 3,300 $\mu$

$$W_i = \frac{44.5}{(425)^{0.23}(1.61)^{0.82}\left(\frac{10}{\sqrt{1338}} - \frac{10}{\sqrt{13300}}\right)}$$

$$= \frac{44.5}{(4.03)(1.48)(0.553 - 0.213)}$$

$$\therefore W_i = \frac{44.5}{2.03} = 23.0 \ kwh/t$$

$$W = \frac{10(W_i)}{\sqrt{P}} - \frac{10(W_i)}{\sqrt{F}}$$

$$= \frac{330}{18.1} - \frac{330}{46.9} = 7.46 \ kwh/t$$

# SCREEN ANALYSES

**AMAX** 805.7
Extractive R. & D. Inc.

Job No.
Test No.
Date:

| Material | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample ID | | | | | | | | | | | | | |
| Starting weight | | | grams | | | | grams | | | . | | | grams |
| After wet screening | | g | % | | | g | % | | | g | | | % |
| After dry screening | | g | % | | | g | % | | | g | | | % |
| Loss | | g | % | | | g | % | | | g | | | % |

| Tyler Mesh Std. | Size Micron | g | % | Cum Ret'd | Cum Passing | g | % | Cum Ret'd | Cum Passing | g | % | Cum Ret'd | Cum Passing |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 4,750 | | | | | | | | | | | | |
| 6 | 3,350 | | | | | | | | | | | | |
| 8 | 2,360 | 34.8 | 17.5 | 17.5 | 82.5 | 40.0 | 16.1 | 16.1 | 83.9 | | | | |
| 12 | 1,400 | 28.7 | 14.4 | 31.9 | 68.1 | 38.3 | 15.4 | 31.5 | 68.5 | | | | |
| 16 | 1,180 | 24.9 | 12.5 | 44.4 | 55.6 | 29.0 | 11.6 | 43.1 | 56.9 | | | | |
| 20 | 850 | 21.2 | 10.7 | 55.1 | 44.9 | 27.1 | 10.9 | 54.0 | 46.0 | | | | |
| 28 | 600 | 17.0 | 8.5 | 63.6 | 36.4 | 20.4 | 8.2 | 62.2 | 37.8 | | | | |
| 35 | 425 | 14.6 | 7.3 | 70.9 | 29.1 | 18.8 | 7.6 | 69.8 | 30.2 | | | | |
| - 35 | 300 | 57.8 | 29.1 | 100 | | 75.4 | 30.2 | 100 | | | | | |
| 65 | 212 | | | | | | | | | | | | |
| TOTAL WEIGHT | | 199.0 | | | | 249.0 | | | | _Composite_ | | | |
| 150 | 106 | | | | | | | 8 | | 74.8 | 16.7 | 16.7 | 83.3 |
| 200 | 75 | | | | | | | 12 | | 67.0 | 15.0 | 31.7 | 68.3 |
| 270 | 53 | | | | | | | 16 | | 53.9 | 12.0 | 43.7 | 56.3 |
| (325) | 45 | | | | | | | 20 | | 48.3 | 10.9 | 54.6 | 45.4 |
| 400 | 38 | | | | | | | 28 | | 37.4 | 8.3 | 62.9 | 37.1 |
| | | | | | | | | 35 | | 33.4 | 7.5 | 70.4 | 29.6 |
| | | | | | | | | -35 | | 133.2 | 29.6 | 100 | |
| | | | | | | | | TOTAL | | 448.0 | | | |

# APPENDIX C

## ORDER-OF-MAGNITUDE CAPITAL & OPERATING

## COST CALCULATION FOR A PLANT TREATING

## DIFFERENT TONNAGES

## PROGRAM OBJECTIVE

Order-of-magnitude estimate (capital & operating cost) for a plant to treat

a.   100 tpd

b.   250 tpd   (Max. size portable plant)

c.   500 tpd

d.   1000 tpd

e.   5000 tpd

f.   10,000 tpd

## TONNAGE PROCESSED

a.   5 tph @ 85% availability, 24 hpd or 3 shift basis

b.   12.5 tph

c.   23 tph @ 90% availability

d.   46 tph

e.   231 tph

f.   462 tph

Methodology and Assumptions for Calculating
Capital and Operating Costs for
A Plant to Process Pb/Zn Material

1.  Capital cost was estimated for 100 tpd plant by sizing and
    costing the major pieces of equipment in the process and
    applying the factors for installation, piping, etc.  These
    are given in the book titled, "Mining and Mineral
    Processing Costs and Preliminary Capital Cost
    Estimations", CIMM Special Vol. No. 25.

2.  The cost for 250 tpd was estimated from the cost for 100
    tpd plant using the following equation:

    $$\frac{C_1}{C_2} = \left(\frac{Capacity_1}{Capacity_2}\right)^{0.6}$$

    where $C_1$ and $C_2$ are capital costs.

3.  Capital cost for 500 tpd plant was calculated by two
    different methods:

    a)  Sizing and costing of major pieces of equipment in
        the process and applying the factors for
        installation, piping, etc.  Fixed capital cost
        estimate was = $4,000,000.

    b)  Using regression equations developed by O'Hara and
        given in the CIMM Special Vol. No. 25, fixed capital
        cost was estimated to be = $8,000,000.

4.  The average fixed capital cost of $6,000,000 is used in
    the study.  The accuracy of this type of estimate is =
    35%.  The two estimated numbers fall within this range.

5.  The fixed capital cost for 1000, 5000 and 10,000 tpd
    plants was calculated using the equation:

    $$\frac{C_1}{C_2} = \left(\frac{Capacity_1}{Capacity_2}\right)^{n}$$

    where n = 0.6 for 1000 tpd and
          0.7 for 5000 and 10,000 tpd

6.  Mining cost is assumed to be fixed at $2.50/ton.  The process supplies per ton also was assumed to be fixed.

7.  Cost for utilities and labor are dependent on size of plant.  The former will increase and the latter will decrease with the increase in size of plant.

8.  Revenue is estimated based on the following assumptions:

    a)  Head grade of material is 0.5% Pb and 0.5% Zn.

    b)  The process will recover 80% of Pb and Zn values in a marketable-grade product.

    c)  The selling price of lead and zinc is 30¢ and 40¢ per pound, respectively.

```
                        Ore
                         |
                         v
                      Crushing
                         |
                         v
          ┌──────────►Grinding
          │              |
          │              v
          └───────Classification
                         |
                         v
                      Rougher───────────────────►Concentrate
                     Flotation                        │
                         |                            │
                         v                            │
                     Thickening                       │
                         |                            │
                         v                            │
                    Conditioning                      │
                   (Desulfidizing)                    │
                         |                            │
                         v                            v
                      Rougher───────────────────►Concentrate
                     Flotation                        │
                         |                            │
                         v                            v
                      Tailing◄─────────────┐       Regrind
                         |                 │          │
                         v                 │          │      ┌──────┐
  O/F ◄──────────────Thickening          ┌─│──────────│──────┘      │
   to                    |               │ └──►Cleaner Flot.────────┘
  Process                |               │         │
  H2O                    v               │         v
                     Disposal            └──Recleaner Flot.
                                                   │
                                                   v
                                            Final Product


Flowsheet Alternative No. 1


                        C-2
```

```
                              Ore
                               │
                               ▼
                           Crushing
                               │
                               ▼
            ┌─────────────►Grinding
            │                  │
            │                  ▼
            └──────────Classification
                               │
                               ▼
                           Rougher
                           Flotation──────────────────────┐
                               │                          │
                               ▼                          │
   Fines◄──────────────Cycloning                          │
     │                         │                          │
     │                         ▼                          │
     │                   Conditioning                     │
     │                   (Sulfidizing)                    │
     │                         │                          │
     │                         ▼                          │
     │                    Rougher────────────────────────►┤
     │                    Flotation                       │
     │                         │                          ▼
     │                         ▼          Concentrate────►Regrind
     │                     Tailing                          │
     │                         │                            ▼
     └────────────────►├◄────────────────────────────Cleaner
                         ▼                             Flotation ◄──┐
   O/F to◄──────────Thickener                             │        │
   Process               │                                ▼        │
   H₂O                   │                            Recleaner─────┘
                         ▼                            Flot.
                     Disposal                            │
                                                         ▼
                                                  Final Product
```

Flowsheet Alternative No. 2

```
                        Ore
                         │
                         ▼
                     Crushing
                         │
                         ▼
          ┌───────►Grinding
          │              │
          │              ▼
          └───Classification
                         │
                         ▼
              Gravity────────►Concentrate────────►Regrind
              Separation                             │
                         │                           ▼
                         ▼                     3 Stage Cleaner
                     Tailing                   Flotation in
                         │◄──────────────────────Counter Current
                         ▼                        Manner
     O/F To ◄───────Thickener                      │
     Process             │                         ▼
     H₂O                 │                       Final
                         ▼                       Product
                     Disposal
```

Flowsheet Alternative No. 3

# COST ESTIMATION METHOD NO. 1 FOR 500 tpd PLANT

**Fixed Capital Cost Estimates: Processing Plant**      (500 tpd)
(Ref: O'Hara, CIM Bulletin, Feb. 80)         M&S = 845
                                          $1C = $0.75 U.S.

1. Plant-Site Clearing and Mass Excavation

$$C_1 = 56637 \ F_5 \ T^{0.3}$$

$$= 56637 \times 1.0 \times (500)^{0.3} \times (845/800)$$

$$= 56637 \times 1 \times 6.45 \times \frac{845}{800} \times 0.75$$

$$= \$289,393$$

2. Concrete Foundation and Detailed Excavation

$$C_2 = 28319 \ (1.8) \ (500)^{0.5} \times (845/800) \times 0.75$$

$$= \$902,949$$

3. Crushing Plant, Coarse Ore Storage, Conveyors

$$C_3 = 63717 \ (500)^{0.5} \times \frac{845}{800} \times 0.75$$

$$= \$1,128,673$$

4. Concentrator Building

$$C_4 = 42478 \ (500)^{0.5} \times 1.8 \times \frac{845}{800} \times 0.75$$

$$= \$1,354,408$$

5. Grinding Section, Fine Ore Storage

$$C_5 = 11328 \ F_g \ T^{0.7}$$

$$= 11328 \times 1.8 \times (500)^{0.7} \times 1.056 \times 0.75$$

$$= \$1,251,497$$

6. Flotation and/or Processing Section

$$C_6 = 3540 \ F_p \ T^{0.7}$$

$$= 3540 \times 1.6 \times (500)^{0.7} \times 1.056 \times 0.75$$

$$= \$347,638$$

7. Thickening & Filtration Section

$$C_7 = 7080 \times 1.6 \times (500)^{0.5} \times 1.056 \times 0.75$$

$$= \$200,615$$

8. Concentrate Storage and Loading　　(Conc = 5% of Feed)
　　　　　　　　　　　　　　　　　　　　( = 25 tpd )

$$C_8 = 5664 \, T_C^{0.8}$$

$$= 5664 \, (25)^{0.8} \times 1.056 \times 0.75$$

$$= \$58,911$$

9. Electrical Power Supply and Distribution

$$P = \text{peak load}$$

$$= 136 \, (500)^{0.5}$$

$$= 3041 \text{ kw}$$

Utility Substation

$$C_{93} = 496 P^{0.8}$$

$$= 496 \, (3041)^{0.8} \times 1.056 \times 0.75$$

$$= \$240,226$$

Low Voltage Lines

$$C_{94} = 850 P^{0.8}$$

$$= 850 \, (3041)^{0.8} \times 1.056 \times 0.75$$

$$= \$411,678$$

10. Tailing Storage

$$C_{10} = 4248 \, (500)^{0.5} \times 1.056 \times 0.75$$

$$= 75,230$$

Fresh Water $Q = 12 \, (500)^{0.6}$

$$= 500 \text{ IGPM}$$

Reclaim Water $Q = 0.026 \, T^{1.2}$

$$= 0.026 \, (500)^{1.2} = 45 \text{ IGPM}$$

11. Water Supply

$$C_{111} = 496\ LQ^{0.9} \quad \text{where } L = \text{miles of pipe}$$
$$L = 1 \text{ mile}$$

$$= 496 \times 1 \times (500)^{0.9} \times 1.056 \times 0.75$$

$$= \$105,507$$

$$C_{112} = 3257\ Q^{0.6}$$

$$= 3257\ (500)^{0.6} \times 1.056 \times 0.75$$

$$= \$107,380 \quad \text{for fresh water pump}$$

$$C_{113} = 4248\ Q^{0.6}$$

$$= 4248\ (500)^{0.6} \times 1.056 \times 0.75$$

$$= \$140,052$$

12. Plant Services

Operating Labor for Open Pit Mine

$$N_1 = 0.075\ (500)^{0.5} + 0.110\ (500)^{0.5} + 0.035\ (500)^{0.7}$$
$$+ .210\ (500)^{0.5} + 0.108\ (500)^{0.5} + 0.070\ (500)^{0.5}$$

$$= 0.573\ (500)^{0.5} + 0.035\ (500)^{0.7}$$

$$= 12.8 + 2.7 = 15.5$$

Processing Plant

$$N_3 = 1.10\ (500)^{0.5} = 24.5$$

Operating Labor = 40

General Plant Services

| | | | | |
|---|---|---|---|---|
| Substation electrical | = | 0.03 x 40 | = | 1.2 |
| Surface Plant & Road Maintenance | = | 0.04 x 40 | = | 1.6 |
| Total | | | = | 3.0 |
| Administration (0.07 x 40) | | | = | 3.0 |
| Total | | | = | 46.0 |

$$C_{12} = 11,328 \ (46)^{0.8}$$

$$= 242,303 \times 1.056 \times 0.75$$

$$= \$191,904$$

13. Access Road

$$C_{131} = 424779 \ R \qquad\qquad R = \text{miles of road}$$

no cost assumed in this study

15. Feasibility, plan, design

$$0.05 \times \left[ [289,393] + [902,949] \right] + 0.7 \ [1,128,673 +$$

$$1,354,408 + 1,251,497 + 347,638 + 200,615 + 58,911 +$$

$$411,678 + 75,230 + 105,507 + 107,380 + 140,052 + 191,904]$$

$$= 59,617 + 0.07 \ (5373493)$$

$$= \$376,144$$

| Item No. | | Cost |
|---|---|---|
| 1 | | $ 289,393 |
| 2 | | 902,949 |
| 3 | | 1,128,673 |
| 4 | | 1,354,407 |
| 5 | | 1,251,497 |
| 6 | | 347,638 |
| 7 | | 200,615 |
| 8 | | 58,911 |
| 9 | | 651,904 |
| 10 | | 75,230 |
| 11 | | 352,939 |
| 12 | | 191,904 |
| 13 | | - |
| 14 | | - |
| 15 | | 435,761 |
| 16 | (10% of items 1-14) | 680,606 |
| 17 | (Adm. 5% of 1-14) | 340,303 |
| Total | | $8,262,731 |

Capital Cost/ton/day = $16,525

## ESTIMATE OF OPERATING COST

Assume average salary $23,400 = $600/wk Canadian

A.  Open Pit Mine

    1.  Labor

$$C_{11} = 93.35\ Tp^{0.5} + 5.724\ Tp^{0.7}$$

          (all ore and waste processed)

$$= (93.35\ (500)^{0.5} + 5.724\ (500)^{0.7}) \times 0.75$$

$$= (2087 + 444) \times 0.75$$

$$= 1898$$

    2.  Supplies

$$C_{12} = (18.97\ (500)^{0.5} + 1.756\ (500)^{0.7} + 1.274\ (500)^{0.8}) \times 0.75$$

$$= (424 + 136 + 184) \times 0.75$$

$$= \$558$$

B.  Processing Plant

$$C_2 = (148.3\ (500)^{0.5} + 30.44\ (500)^{0.7}) \times 0.75$$

$$= (3316 + 2359) \times 0.75$$

$$= \$4256$$

C.  Power

$$C_4 = 54.34\ (500)^{0.5} \times 0.75$$

$$= \$911$$

D.  Supplies General

$$C_5 = 8.5\ (500)^{0.5} \times 0.75$$

$$= \$1430$$

Operating Cost    =   $7,623/day

E.  Wages/General Plant Services

Electrical $C_6$ = 1.35 (108.4 x 4 x 1) x 0.75 = 110

Surface $C_7$ = 1.35 (84.5 x 2) x 0.75 = 171

Total = 281

F.  Wages/Administration Exp.

General Adm. = 1.35 (9.49 x 3) x 0.75 = 29

General Expense = 6.38 x 3 x 0.25 = 14
                                                        --
Total                                                   $43

Total Cost = 1,898 + 558 + 4,256 + 911 + 143 + 281 + 43
           = 8,090

Cost/ton = $16.18

Crushing Circuit

```
|COARSE ORE |
|STOCK PILE |
      |
      v
| COARSE ORE     |
| BIN & VIBRATING|
| FEEDER         |
      |
      v
| SINGLE ROD  |---------> | CONE CRUSHER |
| DECK SCREEN |                  |
      |                          v
    |v SIZE|           - - - - - - - - - -  ---> | CONE CRUSHER |
      |                          |
      v                          |
| SINGLE DECK SCREEN |<----------
      |
    - - ->  | FINE ORE BIN |
```
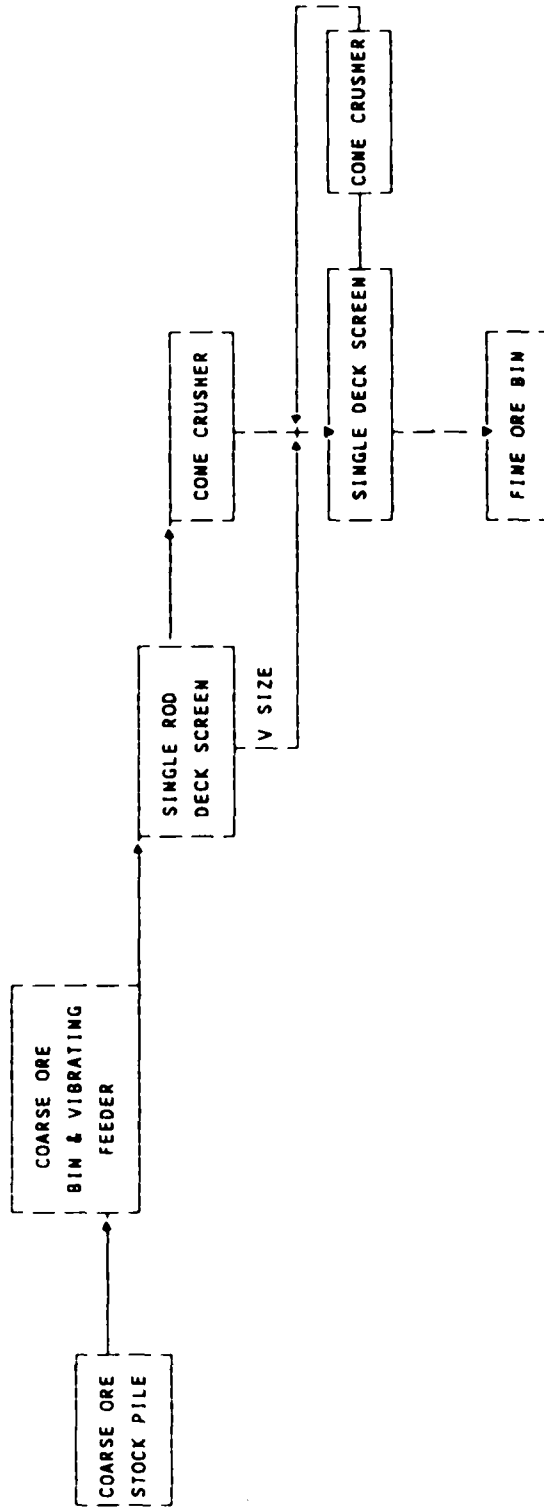
MAJOR EQUIPMENT

1. Vibrating Feeder = $10,000

2. 2- 4' x 8' Single Rod Deck Screen: $2 \times 2141.3 \ (4^2 \times 8) \ 0.4069 \times 1.056 \times 0.75 = \$24,426$

3. 2- 3 ft. short head crusher: $2 \times 12579 \ (3)^{1.742} \times 1.056 \times 0.75 = \$135,066$

4. 2- 32' x 32 1 x 10' ore bins: $2 \times 2.536 \ (10,000) \ 1.025 \times 1.056 \times 0.75 = \$50,571$

Total Equipment Cost = 10,000 + 24,426 + 135,066 + 50,571

= $220,063

## Bin Capacity & Size

| | | |
|---|---|---|
| 1 cu ft weighs | = | 100 lbs. |
| 1 ton material | = | 20 ft$^3$ |
| 500 tons capacity | = | 10,000 ft$^3$ |

## GRINDING CIRCUIT

Ball Mill Feed 80% passing 3/8 inch ($^-$9525 mm)

Product 80% passing 20 mesh    (833 mm)

Wi  =  25

Tons per hour  = 23

$$W = \frac{10\ Wi}{\sqrt{P}} - \frac{10\ Wi}{\sqrt{F}}$$

$$= \frac{10 \times 25}{\sqrt{833}} - \frac{10 \times 25}{\sqrt{9525}}$$

$$= 8.662 - 2.562$$

$$= 6.1\ kwh/ton$$

HP required  =  6.1 x 1.341 x 23

=  188 hp

8 ft. x 8 ft. mill has 215 HP @ 35% loading

Cost =  a (x)$^b$ (L/D)

=  3875.3 (8)$^{2.111}$ (8/8) x 1.056 x 0.75

=  $247,430

Ball Charge  =  20 tons @ $500/ton = $10,000

Mill Liners  =  0.22 x 247,430 = $29,692

Motor Cost  =  378.91 (215)$^{0.8635}$ x 1.056 x 0.75

=  $31,000

Total Cost of Mill   =    247,430 + 10,000 + 31,000

                     =    $288,430

Cyclone Systems      =    $30,000

Grinding & Classification Cost   =    $318,430


## FLOTATION CIRCUIT

Feed @ 30% solids, s.g.  =    3.0

Residence Time           =    12 minutes each stage

Tonnage                  =    23 tph

Cu ft./min/ton solids/hr =    1.43

Two stages:    Cu ft/23 min/ton solids/hr = 1.43 x 24 = 34.3

Total volume required = 34.3 x 23 x 789 ft$^3$

Volume of air factor = 0.80

Total vol. required 10.00 ft$^3$ or 500 ft$^3$ in each stage

Assume each sell 50 cu ft. Total # needed = 20

Cost =    1955.3 (50)$^{0.3079}$ x 20 x 1.056 x 0.75

     =    104,000

Cost of Lauders & paddle @ 10% = 10,400

Motor Hp/cell = 15

Total HP = 15 x 20 = 300

Motor cost =    20 x 378.91 (15)$^{0.8635}$ x 1.056 x 0.75

           =    $62,200

Conditioners = $100,000

Total Cost =    104,000 + 10,400 + 62,200 + 100,000

           =    $276,600

## MISCELLANEOUS EQUIPMENT

Misc. equipment assumed to be thickeners, pumps, filters, driers, storage bins, reagent mixing and distribution system, etc.

Assume that misc. equipment will be 30% of total equipment cost.

Major equipment cost = Crushing + grinding + flotation

= 220,100 + 318,400 + 276,400

= 814,900

Total equipment cost = $\frac{814,900}{0.70}$ = $1,164,200

## TOTAL CAPITAL COST

| | | |
|---|---|---|
| 1. | Purchased equipment cost | $1,164,200 |
| 2. | Installed equipment cost (1.43 x Item 1) | 1,664,800 |
| 3. | Processing piping (10% of Item 2) | 166,500 |
| 4. | Instrumentation (3% of Item 2) | 50,000 |
| 5. | Building & site development (35% of Item 2) | 582,700 |
| 6. | Auxiliaries (water supply, tailing disposal, power, 10% of Item 2) | 166,500 |
| 7. | Outside lines (8% of Item 2) | 133,200 |
| 8. | Total physical plant cost (2 + 3 + 4 + 5 + 6 + 7) | 2,763,700 |
| 9. | Engineering & Construction (25% of Item 8) | 691,000 |
| 10. | Contingency (10% of item 8) | 276,400 |
| | Total Fixed Cost | $3,731,100 |

Capital Cost/ton = 3,731,100/500

= $7,462

## OPERATING COST

Cost Estimate Basis

a.  Capacity 500 tpd

b.  5-day operation, 3 shifts/day

Process Supplies

| | | |
|---|---|---|
| a. | Lime 2lb/ton @ 10¢/lb. | 0.20 |
| b. | Xanthate 350 1 lb/ton @ 75¢/lb. | 0.75 |
| c. | Frother MIBC 0.2 lb/ton @ 50¢/lb. | 0.10 |
| d. | NaHS 2 lb/ton @ 50¢/lb. | 1.00 |
| E. | Flocculant | 0.05 |
| F. | Grinding Balls 2 lb/ton @ $500/ton | 0.50 |
| G. | Grinding Liners 2 lb/ton @ $1000/ton | 1.00 |
| | Total | 3.60 |

Utilities

| | | |
|---|---|---|
| a. | Process water 40 gpt solids @ $0.20/1000 gals | 0.01 |
| b. | Electricity 25kw/ton @ 5¢/kw | 1.25 |
| c. | Natural Gas $1.50/10$^6$ btu-for 1 ton basis | 0.50 |
| | Total | 1.76 |

Labor

| | |
|---|---|
| Operating Labor 6 @ 11.25/hr and 23 tph | 2.93 |
| Supervision @ 25% of Operating Labor | 0.73 |
| Services @ 20% of Operating Labor | 0.59 |
| Technical, Adm. & General Exp. @ 40% of Op. Labor | 1.17 |
| Total | 5.42 |
| Total Operating Cost (not including mining) | 10.78 |
| Assuming Mining Cost $2.50/ton | 2.50 |
| | $13.38 |

Operating Labor Estimation

| | | |
|---|---|---|
| Mining | 3 x 1 = | 3 |
| Crushing Plant | 3 x 1 = | 3 |
| Grinding/Flotation | 3 x 3 = | 9 |
| Miscellaneous Proc. | 2 x 3 = | 6 |
| | = | 21 |
| Extra | | 3 |
| Total | | 24 |

Average Salary = $23,400/yr.

= $11.25/hr.

Lead     -     30¢/lb. selling price

Zinc     -     40¢/lb. selling price

If the ore contains 0.5% Pb and 0.5% Zn and the process recovery is 80% each

1 ton = 10 x 0.80 = 8 lbs. each of Pb and Zn.

Revenue/ton = 8 x (.30 + .40) = $5.60

# COST ESTIMATION FOR 100 tpd (5 tph) PLANT USING METHOD NO. 2

A.  Crushing Circuit

   a.  Jaw Crushing: 12 x 36 in, 40 tph for 1½ inch
       discharge setting

   b.  2 ft short head: 30 tph for 3/8 in. screen opening

   c.  4'x 8'simple rod deck screen

   d.  10 x 20 x 10 ore bin (2000 ft$^3$ capacity)

Jaw Crusher

Cost    =    $2863 (12 \times 36)^{0.4921} \times 1.056 \times 0.75$

        =    46,492

Short Head

Cost    =    $12,579(2)^{1.742} \times 1.056 \times 0.75$

        =    33,325

Screen

Cost    =    12,213

Bin

Cost    =    $2.536 (2,000)^{1.025} \times 1.056 \times 0.75$

        =    4858

Total Equipment Cost  =  46,492 + 33,325 + 12,213 + 4,858

                      =  $96,888

B.  Grinding Circuit

   Wi   =    25

   tph  =    5

   W    =    $\dfrac{10 \times 25}{\sqrt{833}}$  -  $\dfrac{10 \times 25}{\sqrt{9525}}$  =  6.1 kwh/ton

   HP Required  =    6.1 x 1.341 x 5

                =    40.9

5' x 5' mill has 45 HP @ 40% loading

Cost = $3875.3(5)^{2.111}$ x $\frac{5}{5}$ x 1.056 x 0.75

     = $91,739

Ball charge : 5 tons @ $500/ton = $2,500

Mill Liners : 0.12 x 91,739 = $11,008

Motor Cost: $378.91 (45)^{0.8635}$ x 1.056 x 0.75

     = $8,032

Classification ⁻ $10,000

Total Cost = 91,739 + 2,500 + 11,008 + 10,000

     = $115,247

c.    Flotation Circuit

Feed @ 30% solids; t = 12 min each stage

Tonnage = 5 tph

Total vol required = 34.3 x 5 = 171.5 $ft^3$

Correction for vol 0.80

Total vol = 214 $ft^3$ = (220 max.)

Assume each cell is 20 $ft^3$. Cell required = 12

Cost = $12 \times 1955.3 (20)^{0.3079}$ x 1.056 x 0.75

     = 46,742

Cost of launders & paddles = 4,674

Motor HP/cell = 7.5

Total HP = 7.5 x 12 = 90

Motor Cost = $12 \times 378.91 (7.5)^{0.8635}$ x 1.056 x 0.75

     = $20,514

Conditioners: $20,000

Total Cost  =  46742 + 4674 + 20,514 + 20,000

=  91,930

## Miscellaneous Equipment (30% of total equipment cost)

Major equipment cost:  = 96,888 + 115,247 + 91,930

= $304,065

Total equipment cost  = 304,065/0.7

= $434,379

## Total Capital Cost

| | | |
|---|---|---:|
| 1. | Purchase equipment cost | 434,379 |
| 2. | Installed equipment cost ((1) x 1.43) | 621,162 |
| 3. | Process piping | 62,116 |
| 4. | Instrumentation | 18,635 |
| 5. | Building & site development | 217,407 |
| 6. | Auxiliaries | 62,116 |
| 7. | Outside lines | 49,693 |
| 8. | Total physical cost | 1,031,129 |
| 9. | Engineering and construction | 257,782 |
| 10. | Contingency | 103,113 |
| | Total Fixed Cost | 1,392,024 |

Cap. Cost/ton  =  $13,920

## OPERATING COST

Capacity: 100 tpd (5 tph)

     5 day operation, 3 shifts/day

| | | |
|---|---|---|
| Process Supplies | $3.60 | 3.60 |
| Utilities: 20 kw/ton @ 5¢/kw: | 1.00 | |
| Process water: | 0.01 | |
| Natural Gas: | <u>0.40</u> | |
| | 1.41 | 1.41 |

Labor - 2 operators + 1 extra

| | |
|---|---|
| Operator Labor 4 @ $11.25/hr: | 6.75 |
| Supervision & Services @ 25% of Operator Labor | 3.38 |
| Tech. and Adm. @ 25% of Operator Labor | <u>3.38</u> |
| Total | 15.14 |
| Mining @ $2.50/ton | <u>2.50</u> |
| | $17.64 |

# Capital Cost Estimate For Different Tonnages

$$\frac{C_1}{C_2} = \left(\frac{P_1}{P_2}\right)^{0.6}$$

$C_2$ = 1,392,000    $P_2$ = 100 tpd

$C_{250}$ = 1,392,000 $\left(\frac{250}{100}\right)^{0.6}$

= 2,412,100

$C_2$ = 3,731,000,    $P_2$ = 500

$C_{1000}$ = 3,731,000 $\left(\frac{1000}{500}\right)^{0.6}$

= 5,655,100

$C_{5000}$ = 3,731,000 $\left(\frac{5000}{500}\right)^{0.7}$

= 18,699,300

$C_{10,000}$ = 3,731,000 $(20)^{0.7}$

= 30,377,100

## Operating Cost Estimate

Labor:    250 tpd = 12.5 tph

3 operators + 1 maintenance = 4

Cost =    (4 x 11.25)/12.5    =        3.60

Supervision @ 30% of Operating Labor    =    1.08

Tech and Admin. @ 30% of Operating Labor    =    <u>1.08</u>

    5.76

Labor:    1000 tpd = 46 tph

5 op + 1 maintenance =    6.00

Cost = (6 x 11.25)/46    =    1.47

Supervision @ 25% of Operating Labor⌐

Tech. and Admin. @ 40% of Labor⌐    =    0.96

    ----

    2.43

Labor:    5000 tpd = 231 tph

9 op + 1 main. =    10.00

(10 x 11.25)/231 =    0.49

Sup + Tech + Adm. 65% =    <u>0.32</u>

    0.81

Labor:    10,000 tpd = 462 tph

12 + 3 maintenance

(15 x 11.25)/462    =    0.37

65% overhead    =    <u>0.24</u>

    0.61

# Capital Cost Method No. 1 & 2

M #1 500 tpd    =    8,262,700

M #2    =    <u>3,731,000</u>

          =    11,993,700 = \$12 mm.

Average Cost    =    \$6 MM

$$\frac{C_1}{C_2} = \left(\frac{T_1}{T_2}\right)^{0.6}$$

$$C_1 = 6MM \times \left(\frac{1000}{500}\right)^{0.6}$$

          =    9,094,300